A22N

Environment Canada
Environnement Canada

ario Agreement on Great Lakes Water Quality

Ontario
Ministry of the Environment

STANDARDS DEVELOPMENT BRANCH OMOE
36936000007554

PLEASE RETURN TO:
GREAT LAKES LIBRARY

Winter Runoff from an Urban Catchment

Research Report No. 41

Great Lakes Surveys Unit
Water Resources Branch
Ministry of the Environment
135 St. Clair Avenue West
Toronto, Ontario, Canada
M4V 1P5

arch Program for the Abatement of Municipal Pollution under Provisions of the Canada-Ontario Agreement on Great Lakes Water Quality

TD
657
.W35
W56
1974
MOE

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact Service Ontario Publications at copyright@ontario.ca

CANADA-ONTARIO AGREEMENT

RESEARCH REPORTS

These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the Provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies carried out in this program through in-house projects by both Environment Canada and the Ontario Ministry of the Environment, and contracts with municipalities, research institutions and industrial organizations.

The Scientific Liaison Officer for this project was Mr. D.J. Hay, Environment Canada.

Enquiries pertaining to the Canada-Ontario Agreement RESEARCH PROGRAM should be directed to -

Wastewater Technology Centre
Canada Centre for Inland Waters
Environment Canada
P.O. Box 5050
Burlington, Ontario L7R 4A6

Ontario Ministry of the Environment
Pollution Control Branch
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5

TD
657
.W35
W56
1974

Winter runoff from an urban catchment : (January to March 1974) / Waller, D. H.

78812

AZZH

21 -01- 1997
PDB library

WINTER RUNOFF FROM AN URBAN CATCHMENT

(January to March 1974)

by

Great Lakes Surveys Unit
Water Resources Branch
Ministry of the Environment
135 St. Clair Avenue West
Toronto, Ontario, Canada
M4V 1P5

D.H. Waller and W.A. Coulter
Department of Civil Engineering
Nova Scotia Technical College
P. O. Box 1000, Halifax, Nova Scotia

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY

Project No. 74-8-3

This document may be obtained from -

Training and Technology Transfer
Division (Water)
Environmental Protection Service
Environment Canada
Ottawa, Ontario
K1A 0H3

Ontario Ministry of the Environment
Pollution Control Branch
135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

REVIEW NOTICE

This report has been reviewed by the Technical Committee of the Canada-Ontario Agreement on Great Lakes Water Quality and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of either the Ontario Ministry of the Environment or Environment Canada, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Minister of Supply and Services Canada
Cat. No. En43-11/41

ABSTRACT

Information about winter runoff and snowmelt was obtained for a 163 acre combined sewer drainage area in Halifax, Nova Scotia, from January to March of 1974. Limited amounts of data were obtained for: precipitation; dustfall; snow quantity, quality and density; amount and composition of street solids accumulation and of sand used for ice control; composition of runoff due to snowmelt and rainfall; and, composition and flow rate of dry weather flow and combined sewage. The information obtained is discussed in terms of its application to development or testing of runoff quantity and quality models.

RÉSUMÉ

De janvier à mars 1974, on a recueilli à Halifax (Nouvelle-Écosse) des données sur le ruissellement et la fonte des neiges en hiver, pour un bassin de drainage de 163 acres d'un réseau d'égout unitaire. Une quantité limitée de données ont été obtenues sur les précipitations; les retombées de poussières; la quantité, la qualité et la densité de la neige; la quantité et la composition des matières s'accumulant dans les rues et du sable répandu sur la glace; la composition du ruissellement dû à la fonte de la neige et aux précipitations; ainsi que sur la composition et le débit des écoulements par temps sec et des eaux d'égout. Le rapport traite des données obtenues pour leur application à l'élaboration et à l'essai de modèles quantitatifs et qualitatifs du ruissellement.

TABLE OF CONTENTS

		Page
ABSTRACT		i
TABLE OF CONTENTS		iii
	List of Figures	v
	List of Tables	vi
CONCLUSIONS AND RECOMMENDATIONS		vii
1	INTRODUCTION	1
2	DESCRIPTION OF DRAINAGE BASIN	2
3	DATA COLLECTION PROGRAM AND RESULTS	6
3.1	Laboratory Analyses	6
3.2	Data Collection Methods and Results	6
3.2.1	Precipitation	6
3.2.2	Dustfall	10
3.2.3	Sand and salt application	10
3.2.4	Street cleaning	10
3.2.5	Snow removal	10
3.2.6	Sewer and catchbasin cleaning	13
3.2.7	Solids on street surfaces	13
3.2.8	Solids in snow	13
3.2.9	Sewage flow	13
3.2.10	Sewage composition	25
3.2.11	Surface runoff composition	25
3.2.12	ODI-BOD comparison	25
4	DISCUSSION	29
4.1	Runoff Quantity	29
4.1.1	Long-term runoff	29
4.1.2	Runoff from winter storms and snowmelt	31
4.2	Runoff Quality	33
4.2.1	Long-term quality variations	33
4.2.2	Short-term quality variations	36
REFERENCES		38

TABLE OF CONTENTS (CONT'D)

	Page
ACKNOWLEDGEMENTS	39
APPENDIX - Meteorological Data for Months of January, February March, 1974	43

LIST OF FIGURES

Figure		Page
1	Location Map	3
2	Fairfield Road Drainage Basin	4
3	Fairfield Road Drainage Basin - July, 1973	5
4	Mass Balance Diagram	8
5	Summary of Combined Sewage Results - Storm of February 20, 1974	22
6	Summary of Combined Sewage Results - Storm of March 17, 1974	23
7	Summary of Dry Weather Flow Results - May 15, 1974	24

LIST OF TABLES

Table		Page
1	Halifax Meteorological Data	2
2	Data Requirements for Mass Balance of Water and Contaminants	7
3	Project Precipitation Data	9
4	Snow Depth and Density	11
5	Dustfall in Period February 4 - April 5, 1974	11
6	Sand and Salt Application, Halifax Peninsula	12
7	Street Solids Accumulations	14
8	Characteristics of Sampling Sites	16
9	Analyses of City Sand	17
10	Analyses of Snow and Ice	18
11	Dry Weather Flow - Complete Drainage Basin	19
12	Dry Weather Flow - Residential Sub-Area	20
13	Combined Sewage Flow in Winter Rainstorms	21
14	Surface Runoff Composition	26
15	Snowmelt, February 14, 1974	27
16	ODI:BOD Comparison	28

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this project was to obtain information that could be applied to development and testing of quantity and quality models of winter runoff from urban areas. The information obtained is consistent with the terms of reference, scope, and budget of the project. It will be of value in quantifying and testing models representing variations in amount and composition of surface runoff and combined sewage, on a seasonal basis and during storms.

More information is needed, however, which should be obtained by continuous flow measurement and regular sampling of both combined sewage and surface runoff during a complete winter season, with complete records of meteorological and other factors which contribute to runoff flow and composition. The report indicates areas where additional information is required, or where data collection procedures could be improved. When the information obtained herein is applied, further suggestions about future work will undoubtedly emerge.

Throughout this project, continuous liaison was maintained with City of Halifax staff, and full cooperation and access to records were provided by them, but available information proved to be inadequate in terms of detail and precision. Planning for future projects should make certain that adequate city or project staff are available, and city procedures are organized to ensure that complete and precise records of city works practices are maintained.

1 INTRODUCTION

Existing urban wastewater management models do not include representation of quantity and quality variations resulting from snowmelt or winter rainfall, because the models have been developed in areas where snowmelt and frozen ground conditions were not relevant, or because adequate data were not available to provide a sound basis for model development.

This study represents an attempt to provide some of the information that will be needed if adequate models of wastewater variations during winter conditions are to be developed. The project was initiated late in 1973 as an undergraduate student project in the Civil Engineering Department at Nova Scotia Technical College. Interest and financial support provided through the Urban Drainage Subcommittee under the Canada-Ontario Agreement on Great Lakes Water Quality made it possible to enlarge the project in scope and content.

The objective of the expanded project has been to extend earlier work on a 163 acre combined sewer drainage area in Halifax to include consideration of quality and quantity variations due to snowmelt and winter runoff, and to present a report that includes results and assessments in terms of their application to the development of quality and quantity models.

2 DESCRIPTION OF DRAINAGE BASIN

The location of the drainage basin on which this study is based is shown on Figure 1. The metropolitan region, which includes the City of Halifax and the adjoining City of Dartmouth, has a population of about 250,000. The City of Halifax, which occupies 16,000 acres, has a population (1971 Census) of 122,000. The peninsula shown in Figure 1, which was the City of Halifax prior to annexation of surrounding areas in January, 1969, occupies 4,522 acres and has a population (1971 Census) of 79,255. Sewers in the older, peninsular portion of the city are almost all combined.

The drainage basin is shown in Figures 2 and 3. The size of the area is 163.2 acres. Land use in most of the area is residential. Population, estimated from the 1971 Census, is 4,470 persons. A commercial area (1-3 storey buildings) on both sides of Quinpool Road, occupies 13.5 acres, 8 percent of the total area. Table 1 summarizes meteorological data for the Halifax region.

TABLE 1. HALIFAX METEOROLOGICAL DATA
(Long-Term Means)

Annual Mean Monthly Temperature	44.3°F
Annual Snowfall (rainfall equivalent)	7.9 inches
Annual Rainfall	46.3 inches
Annual Precipitation	54.2 inches

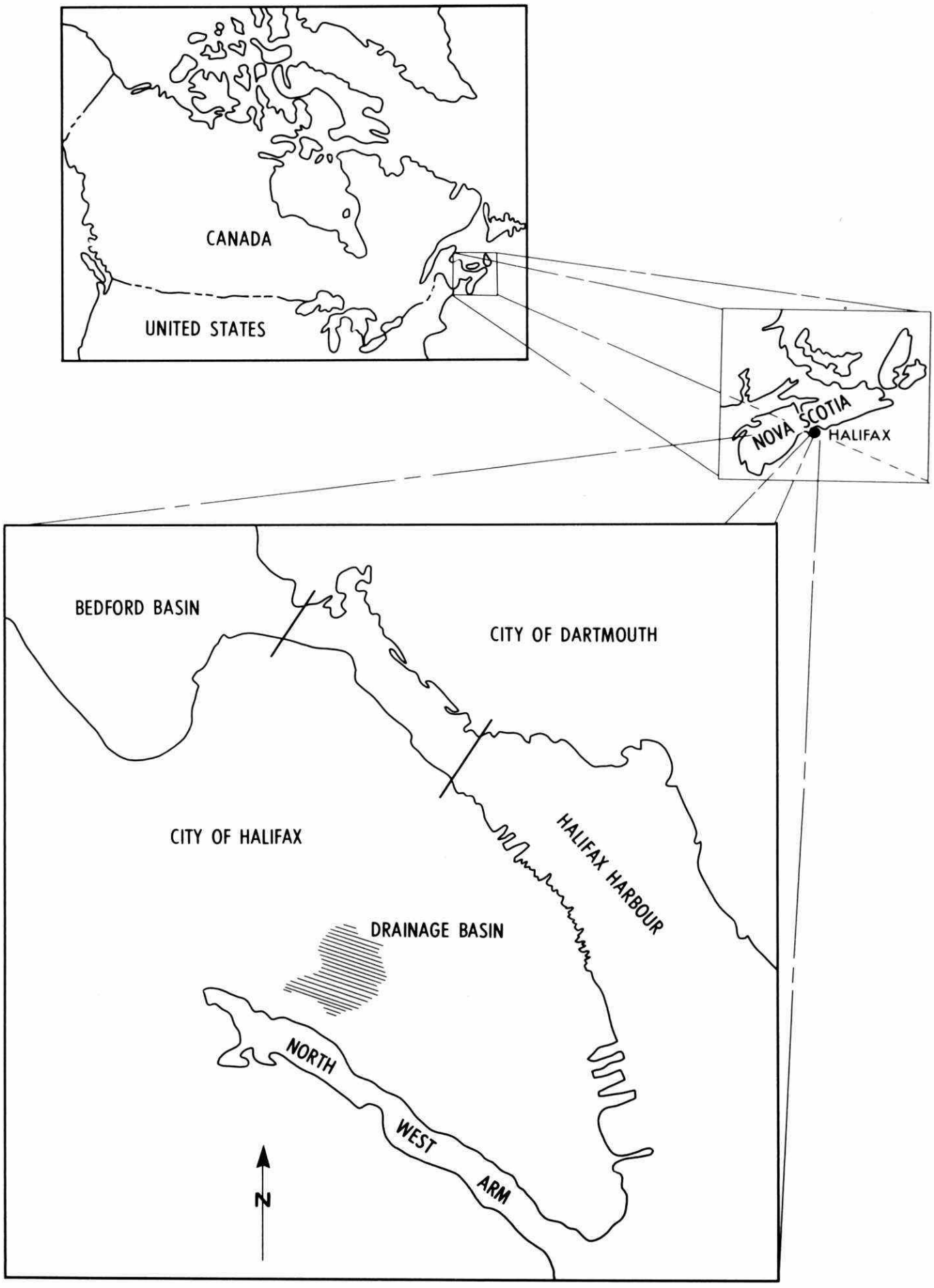
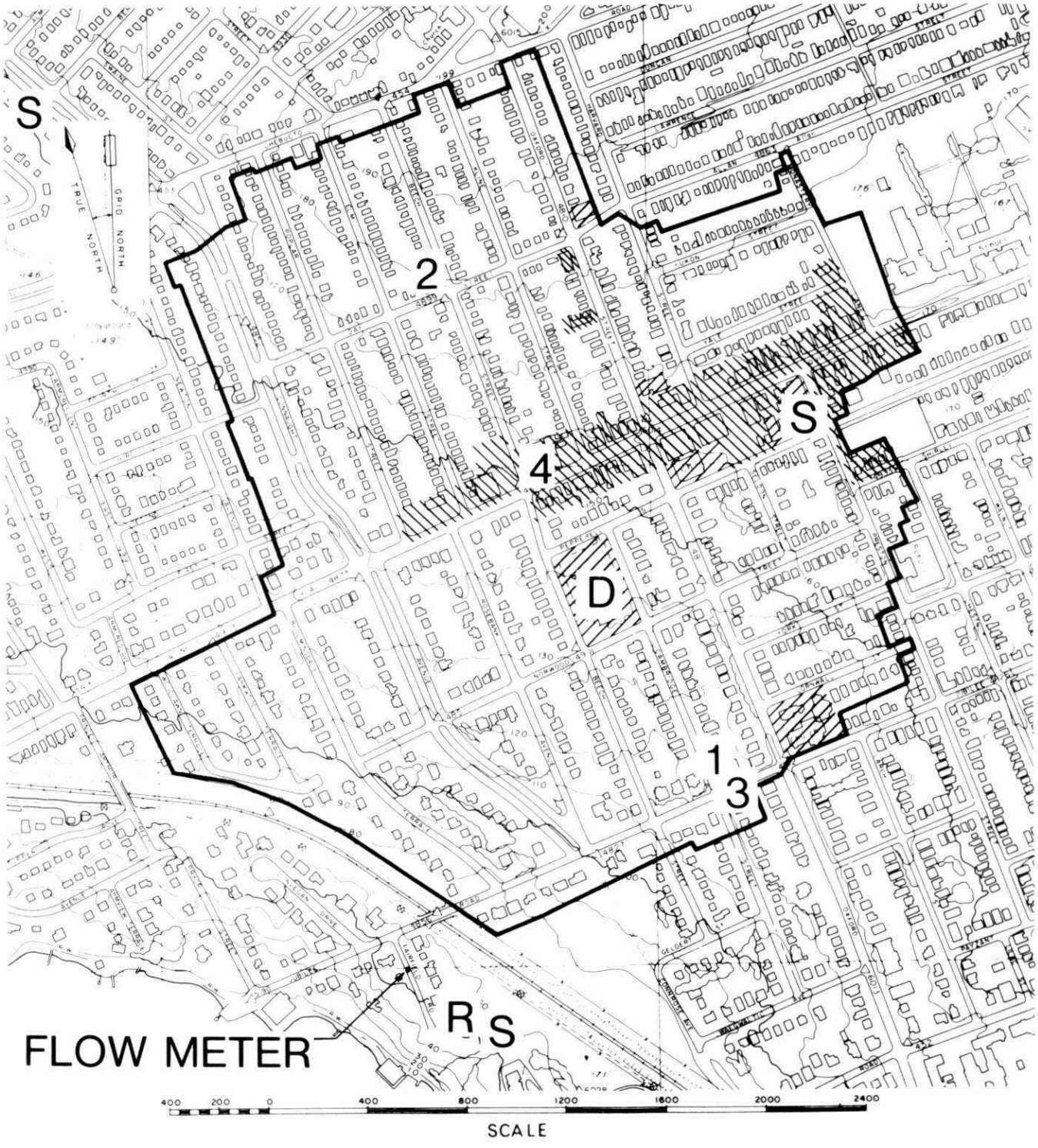


FIGURE 1 LOCATION MAP



LEGEND

- DRAINAGE BASIN BOUNDARY
- INSTITUTIONAL LAND USE
- COMMERCIAL LAND USE
- D DUSTFALL COLLECTOR
- R RAIN GAUGE
- S SNOW BOARDS
- 2 STREET SAMPLING SITES

FIGURE 2 FAIRFIELD ROAD DRAINAGE BASIN

FIGURE 3 FAIRFIELD ROAD

DRAINAGE BASIN

JULY 1973

3 DATA COLLECTION PROGRAM AND RESULTS

The objective of the data collection program was to obtain as much information as possible about inputs, discharges, and storages of water and water-borne contaminants from a single drainage basin for specified periods of time during winter conditions. Table 2 and Figure 4 summarize the components of a mass balance and the relationships among them. Table 2 indicates the items for which field data were sought, those for which recorded data were obtained, and those for which acquisition of the relevant data was considered impracticable.

Field data were collected in the period mid-January to mid-May, 1974.

3.1 Laboratory Analyses

Most laboratory analyses were conducted in accordance with Standard Methods (1). Suspended solids analyses were conducted using the procedure described by Wyckoff (2). ODI tests were conducted according to the method of Westerhold (3), as modified by MacNeil (4). Sieve analyses were carried out after air drying, in a Tyler portable sieve shaker; samples were shaken for 15 minutes at 500 rpm. Most of the analyses reported herein were conducted by the Nova Scotia Pathology Institute.

3.2 Data Collection Methods and Results

3.2.1 Precipitation

AES records of temperature and daily precipitation were obtained for the weather station at CFB Shearwater. This station is located about five miles east of the drainage basin considered in this study, on the opposite side of Halifax Harbour, and is considerably more exposed than the urban location. The AES data are presented in the Appendix which also includes relative humidity and wind speed data from this station.

Additional precipitation data were obtained from a Taylor standard rain gauge and by three snow boards, installed at the locations shown in Figure 2. Daily precipitation was recorded from January 25th to March 19th. The results are presented in Table 3.

TABLE 2. DATA REQUIREMENTS FOR MASS BALANCE OF WATER AND CONTAMINANTS

	Availability of Information*
Inputs to Drainage Basin	
Precipitation	F,R
Water Supply	R
Groundwater Inflow	0
Contaminants in Precipitation	F
Dustfall	F
Dirt and Litter Originating in the Area	0
Sand or Salt for Ice Control	R
Outputs from Drainage Area	
Surface Runoff, Sanitary Sewage, Sewer Infiltration (Combined Sewage)	F
Groundwater Outflow	0
Evapo-Transpiration	0
Snow Removal	R
Solids in Combined Sewage	F
Solids in Removed Snow	F
Solids Removed by Sweeping	R
Catchbasin Cleaning	R
Sewer Cleaning	R
Storage	
Snow	F
Solids in Snow	F
Solids on Ground or Roof Surfaces	F
Soil Moisture	0
Groundwater	0
Catchbasin Accumulations	0
Sewer Deposits	0

*F - field data obtained in this study
R - recorded data available from other sources
0 - no information obtained

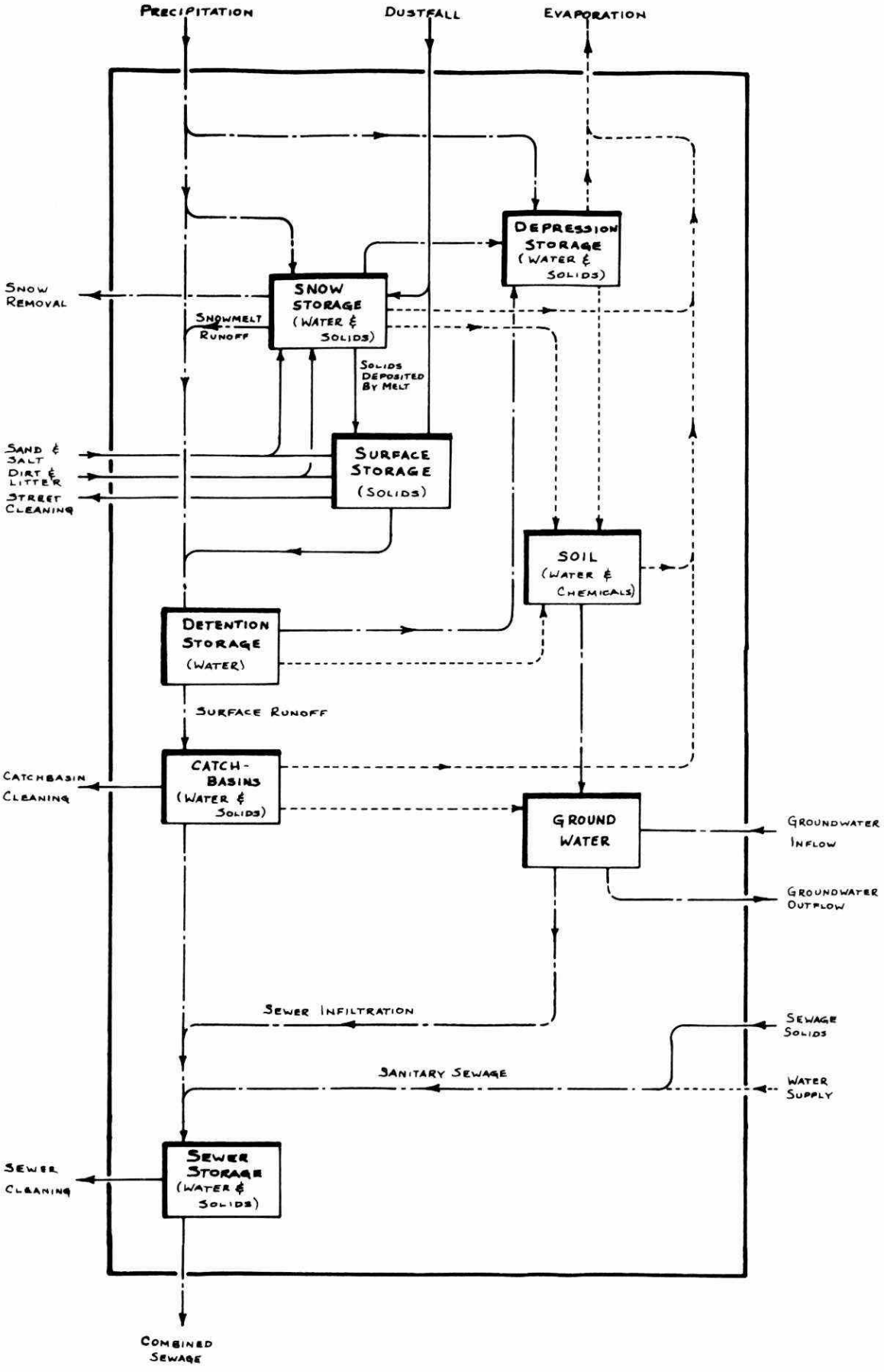


FIGURE 4 MASS BALANCE DIAGRAM

TABLE 3. PROJECT PRECIPITATION DATA

Date		Rain	Station #1 Snow (inches)	Station #2 Snow (inches)	Station #3 Snow (inches)
January	26	TR			
	27	1.09			
	29	0.01			
	31	0.76			
February	1	0.04			
	5,6	0.72	8.6	12.2	12.4
	7		TR*		
	8	0.49	5.0	5.5	5.6
	12	0.02	0.4	0.6	0.6
	14	0.01			
	17	0.12	1.0	0.3	1.2
	18	1.06	7.8	11.3	10.6
	20	1.43			
	21	0.29			
	23	1.02			
	24		0.2	0.3	0.2
	25	0.07	1.6	1.5	1.6
	26	0.63	3.6	3.8	3.7
March	1	0.12			
	2	0.02			
	3	0.01			
	4	0.05			
	5	TR			
	10	0.1	1.5	1.8	1.6
	11	0.09	?	1.5	2.2
	13		TR	TR	TR
	15		TR	TR	TR
	17	0.75			
	18	0.03			

NOTES:

1. Standard rain gauge and snow board located at Station #1, snow boards only at other sites.
2. Dates listed are those on which precipitation occurred.
3. Times at which stations visited daily: #1 - 1330 AST
   #2 - 1340 AST
   #3 - 1345 AST
4. Station #2 is considered to be least exposed to drifting and most reliable of the three stations for snow measurements.

* TR = Trace = negligible amount of rain or snow.

Snow depth was measured and snow density was determined on a number of occasions, to indicate changes in snow accumulations resulting from snowfall or melting. Results are presented in Table 4. Snow density in snowbanks was also measured on a number of occasions, and the results are also included in Table 4.

3.2.2 Dustfall

A single dustfall collector was installed, at the location shown on Figure 2, from February 4th to April 5th. This gauge was designed in accordance with the ASTM Standard Method for collection and analysis of dustfall (6). The gauge was located on the roof of a school, in a position upwind from, and as far as possible away from, the school chimney. Table 5 presents data obtained from the gauge.

3.2.3 Sand and salt application

The City of Halifax Works Department ordinarily applies salt to bus routes and traffic arteries during every winter storm event. In possible icing conditions, a mixture of 90% sand and 10% salt is applied. Sand or salt is applied to residential streets infrequently, when warranted by icing conditions. City records regarding application of sand or salt are not broken down on a street-by-street or storm-by-storm basis. Table 6 contains information relating to the City as a whole.

3.2.4 Street cleaning

Discussions with City of Halifax officials indicated that streets in the study area were not swept between December 17th, 1973 and March 25, 1974. Experience at the Quinpool Road sampling site (Site #4) indicated that shopkeepers in the vicinity of this site occasionally sweep sidewalks and gutters.

3.2.5 Snow removal

The only occasion on which snow was removed from streets in the drainage area was February 12-13, when snow was removed from both sides of the commercial area on Quinpool Road between Beech Street and the eastern boundary of the drainage area. The area of streets and sidewalks on which the removed snow had fallen is 2.6 acres. Two storms in the preceding week deposited 17.6 inches of snow on the area.

TABLE 4. SNOW DEPTH AND DENSITY

A. FLAT SNOW

Date	Station #1 Depth (inches)	Station #1 Density	Station #2 Depth (inches)	Station #2 Density	Station #3 Depth (inches)	Station #3 Density
Feb. 14	19.0	0.22				
16	17.2	0.30				
18	30.0	0.23			24.8	0.22
19			17	0.21	23.5	0.23
20	22.9		10.4		16.7	
21					17.8	0.39
22	9.1	0.25	12.4	0.29	13.8	0.34
28	7.2	0.14	12.7	0.28	10.8	0.28

B. SNOW BANK DENSITY

Date	Cambridge St.	Beech St.	Jubilee Rd.
Feb. 22	0.38		0.40
Mar. 3	0.38	0.40	

TABLE 5. DUSTFALL* IN PERIOD FEBRUARY 4 - APRIL 5, 1974

	Pounds/Acre/60 Days
Suspended Solids (total insoluble residue)	29.2
Volatile Suspended Solids (volatile insoluble residue)	13.2
VSS/SS	0.45
NO_2 - N + NO_3 - N	0.42
NH_3 - N	0.21
Kjeldahl N	<0.20
Total P as PO_4	0.21

*Single gauge designed and located in accordance with ASTM 1739.

TABLE 6. SAND AND SALT APPLICATION, HALIFAX PENINSULA

Month	Tons/Mile		Snowfall (Inches)	Days with Minimum Temperature	
	Sand	Salt		<10°F	<20°F
January	6.49	49.12	11.6	13	19
February	3.06	53.42	40.3	8	19
March	2.13	12.97	8.5	3	15
April	0.12	2.72	4.0	0	0

NOTE: Quantities based on City of Halifax Works Department estimate that 25% of sand applied city-wide was used on 60 miles of arterial streets in the peninsula, and that total salt usage was distributed on 90 miles of city arterial streets.

3.2.6 Sewer and catchbasin cleaning

No sewer or catchbasins in the drainage basin were cleaned during the time period considered in this study.

3.2.7 Solids on street surfaces

Solids accumulated in gutter and on street surfaces were collected, weighed and analysed on three occasions at four sites. Table 7 summarizes the results.

On the first occasion, the samples were collected from a 10 square foot area, 5 feet long in the direction parallel to the curb. This area included most of the evident solids, and on heavily travelled streets made it unnecessary for staff to contend with traffic. On subsequent occasions, samples were collected from a 14 inch wide strip from street centerline to curb; on these occasions the assistance of the Halifax Police Department was enlisted to guide traffic while samples were obtained. Samples were collected by carefully sweeping solids from the sample area with a push-broom, and were transported to the laboratory in plastic bags.

Table 8 summarizes characteristics of the four sampling locations.

Table 9 presents analyses of sand applied in City of Halifax ice control programs. Chemical analyses of the smallest sieve fraction have been carried out for comparison with street solid analyses.

3.2.8 Solids in snow

Two samples were obtained from snow accumulated in snowbanks, to obtain an indication of the nature of materials deposited on sidewalks, grass plots and gutters when snowbanks melt. Results are presented in Table 10. This table also includes analysis of a single sample of ice chipped from the gutter at Site #1 on freezing day.

3.2.9 Sewage flow

Flows from the drainage basin were measured at a critical depth meter at the location shown on Figure 2. Flow measurement instrumentation previously installed at this site was inoperative, and all flow measurements were made by measuring depth and determining flows from the

TABLE 7. STREET SOLIDS ACCUMULATIONS

A. WEIGHT OF ACCUMULATION

Date	Site No.*	Area	Swept ft^2	lb/ft^2	lb/curb mile
Jan. 31	1	5' along	10	0.058	610
	2	curb x	10	0.091	960
	3	2' wide	10	0.020	210
	4		10	0.054	570
Mar. 7	1	14" along	17.6	0.039	3,090
	2	curb x	17.8	0.059	4,740
	3	1/2 street	17.8	0.035	2,780
	4		26.3	0.023	2,750
Mar. 21	1	14" along	17.6	0.19	14,530
	2	curb x	17.8	0.16	1,400
	3	1/2 street	17.8	0.02	12,680

* No sample of Site 4 on March 21; gutter swept by merchants.

B. SIEVE ANALYSES - % RETAINED

Particle Size		Site #1		Site #2		Site #3		Site #4
Sieve #	Opening μ	Mar. 7	Mar. 21	Mar. 7	Mar. 21	Mar. 7	Mar 21.	Mar. 7
3/8	9500	0.4	0.5	32.7	28.4	3.6	5.4	22.3
4	4760	2.1	2.9	33.2	24.9	4.7	8.5	9.4
10	2000	24.0	25.2	9.6	12.1	11.5	16.6	15.6
20	841	29.7	24.3	9.3	13.1	15.2	16.0	15.2
60	250	28.6	23.2	8.6	11.4	33.8	27.1	16.8
140	105	10.8	15.3	4.6	6.3	19.0	17.0	12.2
270	53	3.0	6.4	1.3	2.8	11.4	6.8	7.3
PAN		1.3	2.4	0.6	0.9	0.7	3.3	1.3

C. SCREENING - JAN. 31 SAMPLES

% Retained on 8 x 8 Hardware Cloth*
(Opening 1/8")

Site #1	Site #2	Site #3	Site #4
46%	35%	31%	34%

*Material retained on 8 x 8 cloth included twigs, leaves, pebbles, paper, grass, tree seeds and miscellaneous articles such as cigarette filters.

TABLE 7. (CONT'D)

D. MOISTURE CONTENT OF SAMPLES AS COLLECTED (Air Dried)

Date	Site #1	Site #2	Site #3	Site #4
Jan. 31	67%	18%	11%	20%
Mar. 7	27%	36%	0	0

E. NON-SETTLEABLE FRACTION

Sample from Site #1 on Jan. 31 ovendried, sieved through 8 x 8 hardware cloth (opening 1/8"), diluted with 500 ml distilled water, blended, and portion withdrawn for solids analysis after 10 min. settlement.
Non-settleable fraction - 2.8% by weight.

F. CHEMICAL ANALYSES OF SOLIDS FRACTIONS

(milligrams per gram)

	March 7				March 21		
	Site #1	Site #2	Site #3	Site #4	Site #1	Site #2	Site #3
Suspended Solids							
105-250μ	974	974	942	967	942	976	925
53-105μ	956	950	929	948	934	962	915
< 53μ	936	944	947	949	936	969	924
VSS/SS							
105-250μ	0.08	0.12	0.11	0.17	0.10	0.12	0.08
53-105μ	0.10	0.14	0.09	0.10	0.15	0.07	0.07
< 53μ	0.08	0.11	0.08	0.08	0.11	0.10	0.06
NO_2-N + NO_3-N	All analysis <0.01						
NH_3-N							
105-250μ	0.04	0.10	0.08	0.02	0.04	0.20	0.06
53-105μ	0.06	0.04	0.06	0.02	0.08	0.02	0.06
< 53μ	0.06	0.08	0.06	0.04	0.06	0.26	0.10
Total P as PO_4							
105-250μ	0.02	0.02	0.06	0.02	0.04	0.08	<0.01
53-105μ	0.06	0.04	0.02	0.04	0.04	0.08	0.02
< 53μ	0.04	0.10	0.06	0.04	0.06	0.10	0.06

TABLE 8. CHARACTERISTICS OF SAMPLING SITES

Site No.	Site	Traffic	Land Use	Street Slope	Street Slope at Sampling Point		Mean Slope for Part of Street Drained by Catchbasins
					Jan. 31	Mar. 7&21	
1	Cambridge St. at Jubilee Rd.	Light	Residential	2.4%	0.7%	depression	1.9%
2	Beech St. at Oak St.	Light	Residential	2.2%	2.1%	flat	2.2%
3	Jubilee Rd. at Cambridge St.	Heavy	Residential	3.2%	3.5%	3.5%	3.2%
4	Quinpool Rd. at Beech St.	Heavy	Light Commercial	2.6%	2.2%	1.6%	2.6%

NOTES:

(1) Jubilee Rd. and Quinpool Rd. are among bus routes and traffic arteries that have priority for plowing, to which salt is applied regularly during storms, and to which sand/salt mixture is applied during icing conditions (temperature less than about 10°F). These streets normally plowed curb to curb.

(2) Beech and Cambridge Streets are residential streets that have lower plowing priority and are ordinarily not cleared until storms are over. They are normally not sanded or salted unless slippery due to freezing rain or similar conditions. Not normally plowed curb to curb.

(3) Cambridge St. intersects Jubilee Rd. and may receive shortcut traffic during peak hours. Beech St. is several blocks from an artery and less likely to receive shortcut traffic.

(4) Beech St. was resurfaced with tar and gravel in 1973. Despite sweeping, some loose gravel remains and may be included in street solids samples.

(5) All samples collected on January 31 were obtained from a 5 ft strip beginning 25 ft uphill from each catchbasin. March 7 and March 31 samples were obtained from two locations within 10 ft of each catchbasin.

TABLE 9. ANALYSES OF CITY SAND

A. SIEVE ANALYSES

Particle Size		% Retained	
Sieve No.	Opening μ	City Analysis	Project Analysis
3/8	9500	--	0.3
4	4760	2.4	5.8
8	2380	23.6	--
10	2000	--	39.9
16	1170	25.5	--
20	841	--	27.5
30	590	15.5	--
50	297	11.7	--
60	250	--	14.9
100	149	9.2	--
140	105	--	6.5
200	74	3.8	--
270	53	--	4.4
PAN		8.3	0.8

B. CHEMICAL ANALYSES OF SOLIDS FRACTION <250μ

(milligrams per gram)

Suspended Solids	
105-250μ	670
53-105μ	760
< 53μ	750
VSS/SS	
105-250μ	0.89
53-105μ	0.94
< 53μ	0.93
NO_2-N + NO_3-N	all <0.01
NH_3-N	
105-250μ	0.04
53-105μ	0.06
< 53μ	0.04
Total P as PO_4	
105-250μ	0.12
53-105μ	0.04
< 53μ	0.22

TABLE 10. ANALYSES OF SNOW AND ICE

	Snow Banks, March 6		Ice in Gutter Jan. 29
	Site #1	Site #2	Site #1
Suspended Solids (mg/l)	240	*	3284
Volatile Suspended Solids (mg/l)	50	*	445
VSS/SS	0.21	*	0.14
pH	6.1	6.1	8.0
Conductance	64	12	
Total P, as PO_4 (mg/l)	<0.1	<0.1	
NH_3-N (mg/l)	<0.1	<0.1	
NO_3-N + NO_2-N (mg/l)	<0.1	<0.1	

* Results invalid, sample contaminated by earth in bottom of core.

flume-rating curve. It was expected that a new flow measurement and recording system would be installed before the conclusion of this project, but delays in delivery, assembly and testing of equipment postponed installation.

Dry weather flows were measured periodically during the period of the project. The effects of snowmelt and/or infiltration were apparent through most of the winter period. On May 15th, at the end of a short dry period, infiltration effects were judged to be minimal and dry weather flow was measured and sampled. Results are presented in Tables 11 and 12, and the May 15th results are plotted in Figure 5.

Wet weather flows of combined sewage were measured during three winter rain events. Flows early in each event were missed because of inability to predict the onset of rain. Combined sewage flows are presented in Table 13 and plotted in Figures 6 and 7.

TABLE 11. DRY WEATHER FLOW - COMPLETE DRAINAGE BASIN

Date	Day of Week	Time	Flow (cfs)	Air Temp. in Previous hr °F (Appendix)	Coli $x10^3$ (per 100 ml)	F.C. $x10^3$ (per 100 ml)	F.S. $x10^3$ (per 100 ml)	SS (mg/l)	VSS (mg/l)	VSS/SS	Cond. µ mos.	pH	BOD (mg/l)	Total P as PO_4 (mg/l)	NO_3-N + NO_2-N (mg/l)	NH_3-N (mg/l)
Jan. 28	M	15.00	1.60	45												
30	W	10.20	1.60	33												
Feb. 14	Th	10.10	2.25	37				114	75	0.66	2150	7.1				
21	Th	09.15	2.5	31												
28	Th	11.30	1.10	32												
Mar. 7	T	12.00	1.80	43												
15	F	14.40	1.14	38												
18	M	8.50	1.8	33												
25	M	09.15	1.62	24												
26	T	08.20	1.50	23												
27	W	08.25	1.48	28												
28	T	08.15	1.30	13												
29	F	08.20	1.14	13												
Apr. 9	T	10.55	0.91	31												
10	W	9.25	0.88	43												
14	Su	13.40	0.68	35												
May 15	W	9.10	1.15		48,000	320	70	166	116	0.70	740		165	15	<0.1	19
		10.10	1.04		23,000	260	250	136	83	0.61	590		194	12	<0.1	16
		10.40	0.88													
		11.10	0.86		13,000	740	50	152	101	0.66	580		230	8	<0.1	12
		12.10	0.93		8,300	870	120	106	68	0.64	510		200	4	<0.1	10
		13.10	0.88		21,000	200	60	94	69	0.73	610		180	8	<0.1	14
		14.10	0.88		15,000	700	0	190	148	0.78	620		180	10	<0.1	12
		14.40	0.78													
		15.10	0.93		27,000	606	100	146	107	0.73	610		160	8	<0.1	11
		16.10	0.86		22,000	900	300	144	99	0.69	560		150	8	<0.1	12
		16.40	0.78													
		17.00	0.88		3,500	300	100	92	60	0.65	540		130	5	<0.1	10

TABLE 12. DRY WEATHER FLOW - RESIDENTIAL SUB-AREA

Date	Time	Flow* (gpm)	Coli $\times 10^3$	F.C. $\times 10^3$ (per 100 ml)	F.S. $\times 10^3$	SS (mg/l)	VSS (mg/l)	VSS/SS	Conductivity µ mos.	BOD (mg/l)	Total P as PO_4 (mg/l)	NO_3-N ∓ NO_2-N (mg/l)	NH_3-N (mg/l)
May 15	9.35		2,000	530	26	198	121	0.61	530	260	35	<0.1	24
	11.25	4.9	340	10	6	111	61	0.55	560	160	9	<0.1	16
	13.30	4.2	10,000	0	300	142	78	0.55	530	260	8	<0.1	15
	15.30		2,300	200	120	114	79	0.69	590	140	12	<0.1	17
	17.30		3,500	70	0	72	43	0.60	740	140	13	<0.1	18

* Measured with bucket and stopwatch. May be slightly low due to tendency to overestimate time, because of time used in placing and removing bucket.

TABLE 13. COMBINED SEWAGE FLOW IN WINTER RAINSTORMS

Date	Time	Flow (cfs)	Coliform $\times 10^3$ (per 100 ml)	F.C $\times 10^3$ (per 100 ml)	F.S $\times 10^3$ (per 100 ml)	BOD (mg/l)	SS (mg/l)	VSS (mg/l)	VSS/SS	pH	Cond. µ mos.	Total P as PO_4 (mg/l)	NO_3-N + NO_2-N (mg/l)	NH_3-N (mg/l)	Pb Soluble (mg/l)	Pb Insoluble (mg/l)
Feb. 20	7.58	6.0				370	510	390	0.77	8.2	2390	11	2.9	19.3		
	8.43	11.9*				94	330	150	0.45	7.8	3350	2.5	3.0	11.3		
	9.13	17.0*	750	25	200	35	480	180	0.37	7.2	3200	0.9	2.5	1.7	0.01	0.80
	9.33	11.0				86	400	150	0.36	7.4	2725	1.1	2.3	1.6		
	10.03	14.0				58	300	110	0.36	7.1	2100	1.1	2.3	0.7		
	10.38	13.0				64	220	80	0.36	7.0	1590	0.5	2.2	0.4		
	11.03	17.0				30	150	30	0.23	6.9	1425	0.9	2.3	0.4		
	11.28	20.0	2000	6.5	25	46	160	40	0.23	7.1	1260	0.7	2.3	0.6	0.01	0.35
	11.48	22.0				26	160	30	0.21	6.7	1180	0.4	2.4	0.3		
	12.08	23.5				36	180	30	0.17	6.5	1160	0.5	2.7	0.1		
	12.28	23.5				40	200	40	0.19	6.7	1140	0.5	2.3	0.4		
	12.48	24.0				30	190	40	0.18	6.1	1080	0.3	2.3	0.3		
	13.03	24.3	500	7	20	35	190	40	0.24	6.9	1010	0.3	2.5	0.3	0.05	0.55
	13.23	23.3				25	170	30	0.19	7.0	1070	0.4	2.6	0.3		
	13.43	23.0				23	190	30	0.18	6.8	1050	0.4	2.8	0.3		
	15.48	21.5				20	120	20	0.18	6.7	910	0.4	3.9	0.4		
	16.08	17.0				25	130	20	0.16	6.9	980	0.3	4.6	0.4		
	16.33	15.5	150	1.5	3.6	19	140	30	0.20	6.7	940	0.3	4.6	0.4	0.02	0.30
	16.58	14.0				28	130	30	0.21	7.1	950	0.8	5.3	0.5		
	17.28	11.5				34	80	20	0.30	7.0	980	0.7	6.0	0.5		
Mar. 21	09.15	2.5														
Mar. 1	09.20	2.0														
	10.50	2.0														
	11.20	2.5														
	12.20	4.0														
	13.35	5.5														
	14.20	5.5														
	15.20	3.5														
Mar. 17	10.15	14.5														
	10.30	17.7	2000	6	15		380	100	0.23	6.0	305	0.4	<0.1	1.4		
	10.45	18.0	3400	6	30		360	80	0.23	5.9	287	0.4	<0.1	1.9		
	11.05	17.0	4600	54	30		220	50	0.23	5.8	304	3.0	<0.1	1.1		
	11.25	16.0	500	34	25		160	40	0.29	5.8	261	2.7	<0.1	1.3		
	11.45	14.0	400	44	100		170	40	0.21	5.9	320	2.8	<0.1	1.4		
	12.22	13.0	700	26	150		94	30	0.22	5.9	366	2.1	<0.1	2.2		
	12.52	5.0	600	78	25		49	23	0.47	6.0	648	2.8	<0.1	3.4		
	13.22	9.5	300	50	15		120	32	0.28	5.0	390	0.8	<0.1	1.1		
	13.52	5.0	300	24	5		46	20	0.43	6.0	601	2.7	<0.1	2.1		
	14.45	3.5	1300	32	80		36	23	0.64	6.1	862	2.7	<0.1	3.8		
Mar. 18	08.50	1.8														

* These flow measurements are high by 2-4 cfs.

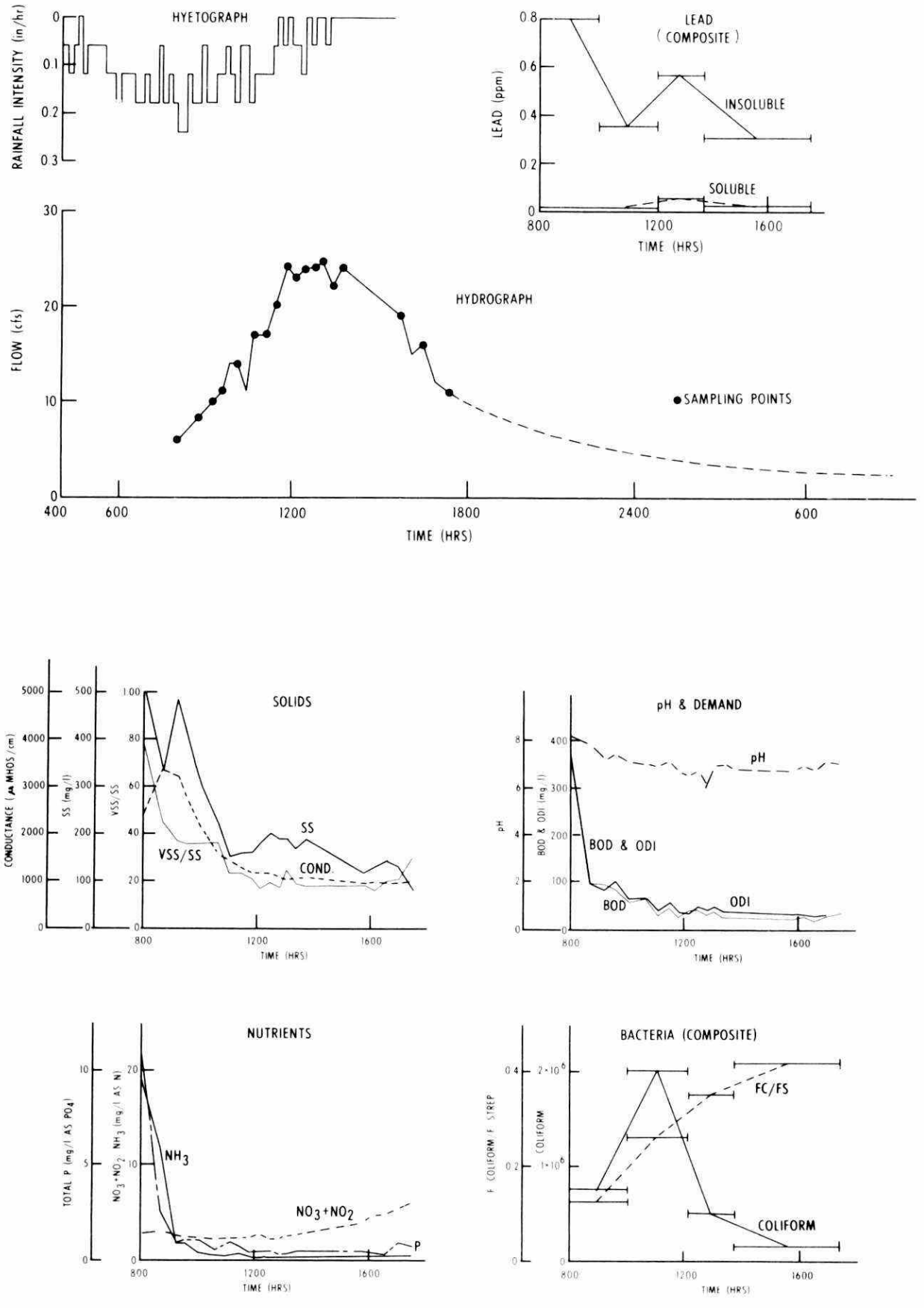
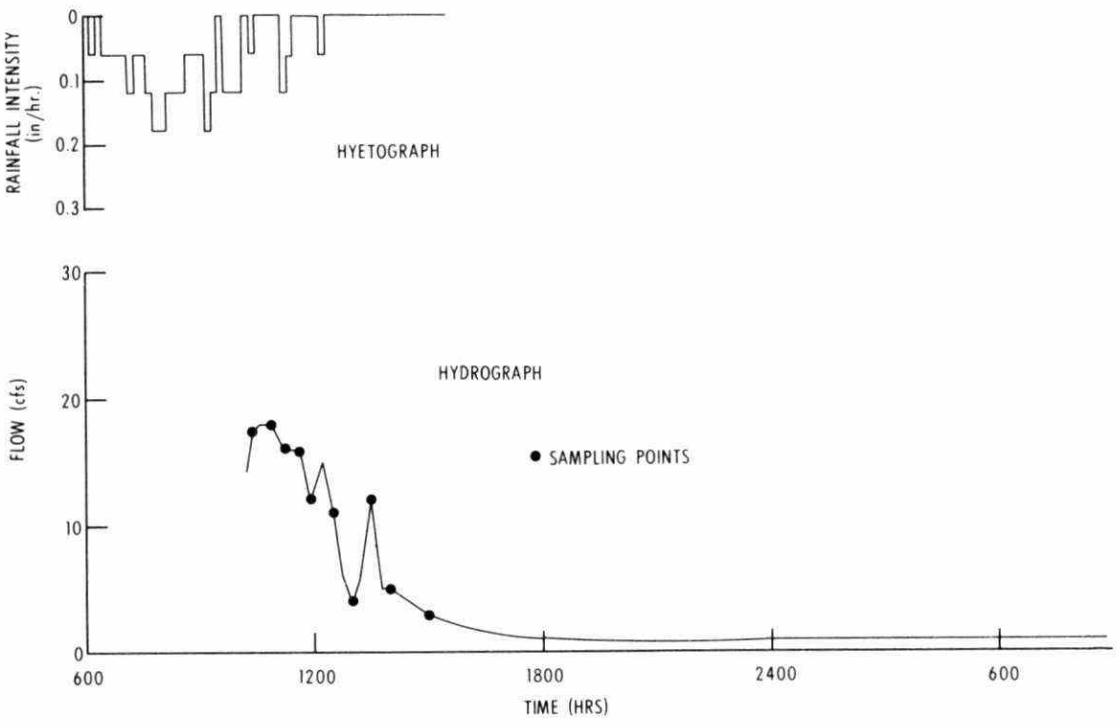


FIGURE 5 SUMMARY OF COMBINED SEWAGE RESULTS - STORM OF FEB. 20, 1974



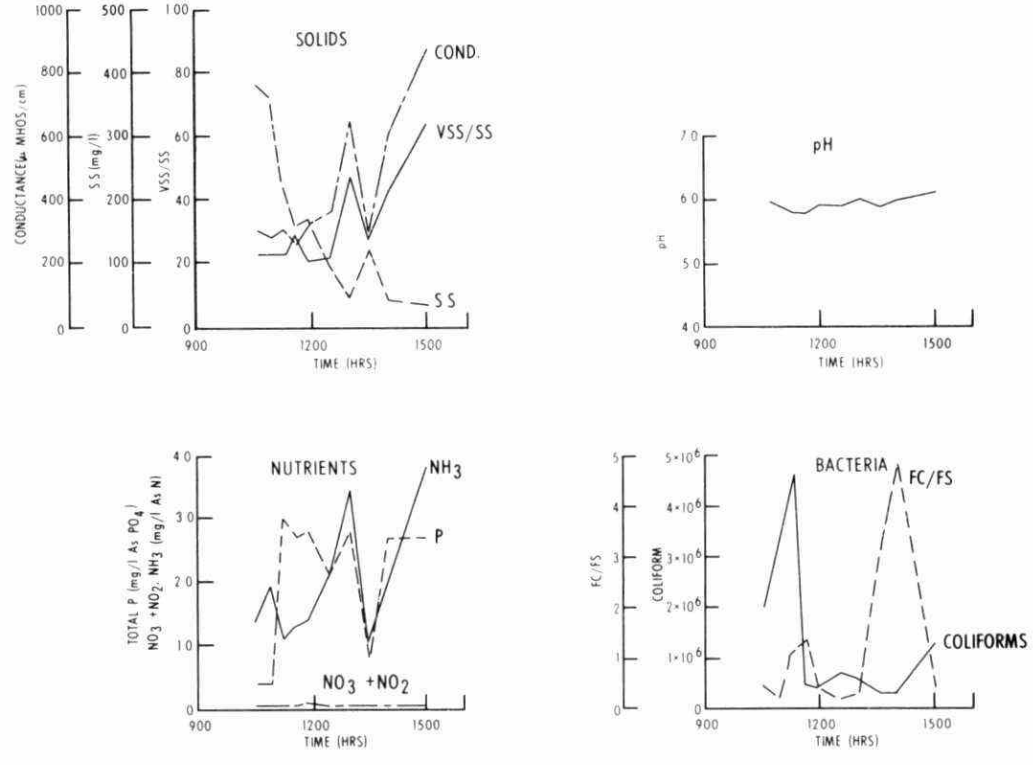


FIGURE 6 SUMMARY OF COMBINED SEWAGE RESULTS – STORM OF MAR. 17, 1974

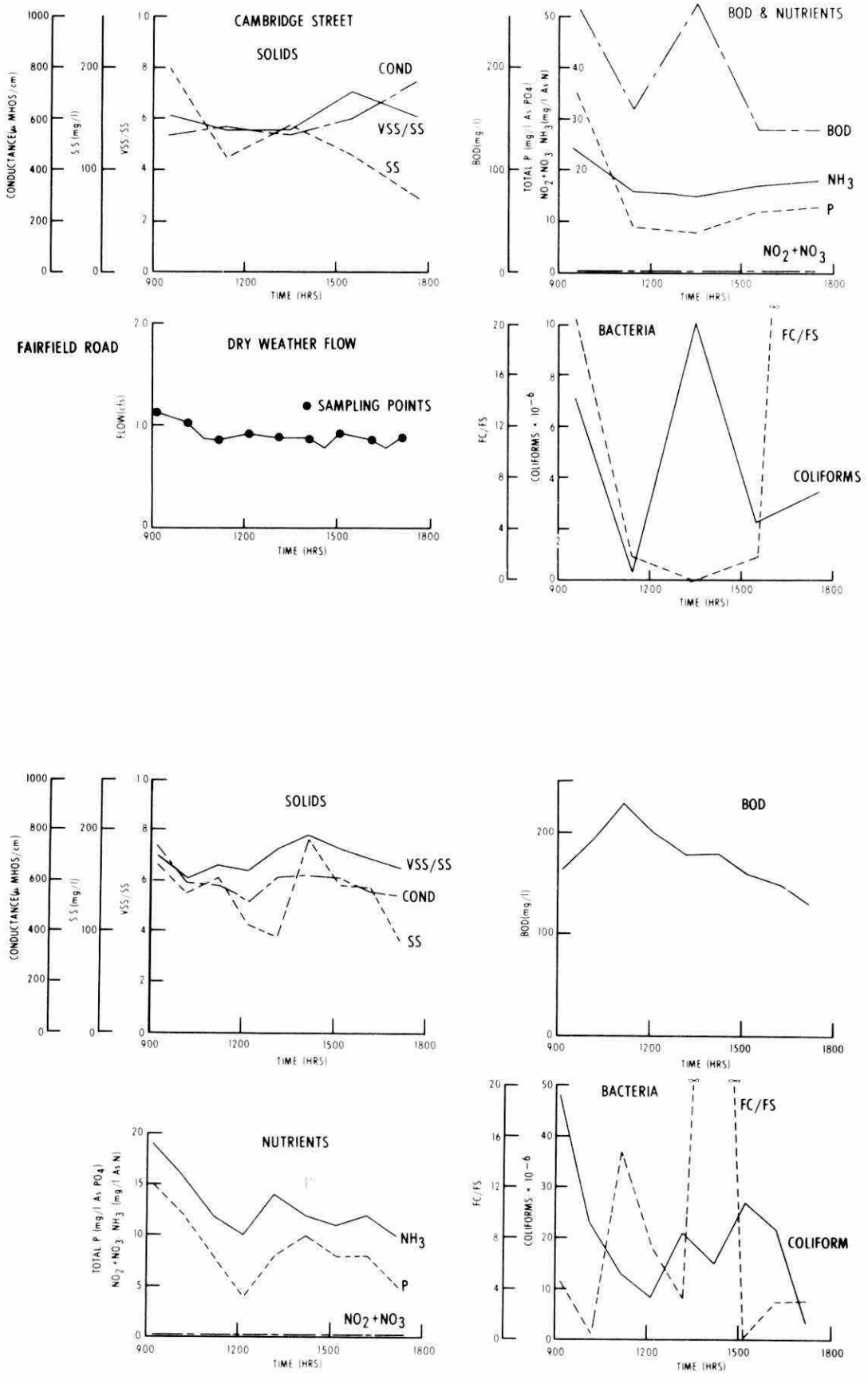


FIGURE 7 SUMMARY OF DRY WEATHER FLOW RESULTS – MAY 15, 1974

3.2.10 Sewage composition

Results of the May 15 sampling of dry weather flow are presented in Tables 11 and 12 (which also includes a single sample of combined sewage collected during a period of snowmelt on February 14) and Figure 5. On May 15, a number of additional samples were collected, and flows estimated by bucket and stopwatch measurements from an entirely residential sub-area of about four acres within the drainage basin. The results are presented in Table 12 and Figure 5.

Combined sewage was sampled and analysed in two of the three storms for which flows were measured. Results are presented in Table 13 and Figures 6 and 7.

3.2.11 Surface runoff composition

Surface runoff during winter rain storms was sampled at the Cambridge Street site during three storm events. During the first of these events, samples were also obtained at three other surface runoff sites. Results are presented in Table 14.

During most periods of snowmelt, rates of surface water runoff in gutters were too low to permit effective sampling. A mild period on February 14 made it possible to obtain samples of runoff from snowmelt at the four sites from which street solid samples were obtained. Snowmelt results are recorded in Table 15.

3.2.12 ODI-BOD comparison

During this study, advantage was taken of the opportunity to extend the results of earlier work at the Nova Scotia Pathology Institute and elsewhere (4, 7) on the relationship between BOD and the oxygen demand index. An ODI analysis was carried out on each occasion that a BOD test was conducted on combined sewage or surface runoff. The results are presented in Table 16.

TABLE 14. SURFACE RUNOFF COMPOSITION

Date	Time	Air Temp. (°F)	Location	Coliform $\times 10^3$ (per 100 ml)	F.C. $\times 10^3$ (per 100 ml)	F.S. $\times 10^3$ (per 100 ml)	BOD (mg/l)	SS (mg/l)	VSS (mg/l)	VSS/SS	pH	Cond. (μ mos.)	Total P as PO_4 (mg/l)	NO_3-N + NO_2-N (mg/l)	NH_3-N (mg/l)	Pb Sol. (mg/l)	Pb Insol. (mg/l)
Jan. 24		40	Site #1				12	143	25	0.17	7.2	1,800					
Feb. 20	09.25	36	Site #1				11	40	10	0.25	6.7	2,300	0.3	3.0	0.2		
	10.45	38	"	0.3	0	0.04	5	40	10	0.25	6.3	405	0.3	2.3	0.1	0.14	0.10
	12.30	42	"				6	50	10	0.20	6.5	320	0.2	1.4	0.1		
	15.35	43	"				6	230	20	0.09	6.3	550	0.2	1.2	0.2		
	16.32	42	"	2.0	0	0.5	9	200	20	0.10	6.6	540	0.2	1.6	0.2	0.03	0.30
	17.10		"														
Feb. 20	10.00	37	Site #2				19	120	30	0.25	5.8	1,750	0.6	2.3	0.2		
	11.05	38	"	4.0	0	0.04	11	60	10	0.17	6.0	950	0.5	1.9	0.2	0.15	0.24
	13.05	42	"				7	50	10	0.20	6.3	600	0.2	1.9	0.2		
	15.45	43	"				9	100	10	0.10	6.0	590	0.3	1.8	0.2		
	16.45	42	"	2.5	0	0.04	7	140	20	0.14	6.2	492	0.3	1.8	0.2	0.10	0.22
	17.15		"														
Feb. 20	08.05	35	Site #3				30	420	50	0.13	6.2	20,000	0.2	2.6	0.3		
	09.35	37	"	4.5	0	0.09	23	490	70	0.14	6.5	6,400	0.3	1.9	0.2	0.10	0.95
	10.55	39	"				19	240	30	0.14	6.3	6,750	0.7	1.7	0.2		
	12.25	42	"				14	750	70	0.10	6.4	8,600	0.1	1.2	0.2		
	15.30	43	"	0.2	0	0.004	11	230	40	0.15	6.7	8,200	0.2	2.2	0.2	0.07	0.07
	16.28	43	"				11	290	30	0.11	6.5	5,750	0.2	2.0	0.2		
Feb. 20	07.50	35	Site #4				48	300	50	0.16	6.6	14,200	0.6	3.4	0.3		
	10.10	38	"	9.0	0	2.4	23	240	40	0.15	6.7	3,050	0.3	1.9	0.2	0.06	0.95
	11.15	38	"				19	190	30	0.15	5.6	2,340	0.3	1.6	0.2		
	13.15	42	"				47	240	40	0.16	6.4	1,550	0.2	1.7	0.2		
	15.50	43	"	2.0	0	0.6	8	150	30	0.18	6.6	1,400	0.2	1.8	0.2	0.03	0.95
	16.50	43	"				12	330	40	0.13	6.6	1,500	0.2	1.8	0.2		
Feb. 23	00.20	38	Site #1				8	128	22	0.17							
	09.10	42	"				3	19	3	0.17							
Mar. 17	08.30	39	Site #1				167	635	124	0.20	7.0	2,350					
	09.10	39	"				41	1251	279	0.22	7.7	290					
	09.40	40	"				13	443	84	0.19	7.5	151					
	10.10	40	"				21	363	71	0.20		119					
	11.00	41	"					149	29	0.19		88					
	11.30	41	"					178	37	0.21		167					
	12.40	43	"					82	17	0.20		141					
	13.15	43	"					284	55	0.19		150					

TABLE 15. SNOWMELT - FEBRUARY 14, 1974

Location	Time	Air Temp. °F	SS	VSS	SS/VSS	pH	NOTES
Site #1	9:45	39	270	49	0.18	6.4	a. Part of sample at Site #1 was standing water i.e. sample may not be representative.
Site #2	10:30	41	414	122	0.29	6.4	
Site #3	9:55	39	3540	622	0.19	6.9	b. Sites #1, 2, and 3 required removal of snow to gain access to curb to obtain
Site #4	10:45	41	2379	572	0.24	7.0	
Combined Sewage	10:10	41	114	75	0.66	7.2	c. Combined sewage flow 2.25 cfs, compared with DWF of about 1 cfs (Table 11).

TABLE 16. ODI:BOD COMPARISON

BOD	ODI	Source of Sample
370	371	Combined Sewage
95	82	" "
94	94	" "
86	100	" "
64	63	" "
58	63	" "
48	59	Surface Runoff
47	42	" "
46	53	Combined Sewage
40	47	" "
36	34	" "
35	44	" "
34	36	" "
30	60	Surface Runoff
30	40	Combined Sewage
30	38	" "
28	31	" "
26	35	" "
25	37	" "
25	26	" "
23	71	Surface Runoff
23	43	" "
23	33	Combined Sewage
20	33	" "
19	37	Surface Runoff
19	39	" "
19	35	" "
19	24	Combined Sewage
14	63	Surface Runoff
12	43	" "
11	38	" "
11	35	" "
11	17	" "
11	16	" "
9	24	" "
9	22	" "
8	36	" "
7	19	" "
7	15	" "
6	22	" "
6	16	" "
5	22	" "

4 DISCUSSION

The objective of this project was to obtain information that could be applied in the development of models of quantity and quality variations in winter runoff. Analysis of the data, and model development, is expected to be part of ongoing programs at the Nova Scotia Technical College and elsewhere.

In the following sections, information obtained by this project is assessed under the headings of Runoff Quantity and Runoff Quality. Factors that affect quality and quantity variations in winter runoff are summarized in Table 2 and Figure 4. All of these factors are important when quantity and quality variations are considered on an annual or seasonal basis. When short term variations (in a single storm event) are considered, these factors are important in the sense that they determine initial states of water or solids in storage, but many of them do not affect variations in quality and quantity during a storm. The following sections discuss information obtained by this project in terms of both long-term and short-term variations.

4.1 Runoff Quantity

4.1.1 Long-term runoff

A model that considers variations in runoff in terms of day-by-day accounting, or a seasonal estimate, must consider the following processes, which are presented in Figure 4:

a) Precipitation - AES records and project records provide an adequate representation of daily precipitation during the period of this study.

b) Evaporation, infiltration and snowmelt - These processes depend largely on meteorological factors which are included in AES records. Correlation between measurements taken at the AES Station and the project drainage basin must be established before AES records can be applied with confidence. This applies particularly to records of snow accumulation, which were not obtained daily for the study area and do not appear to exhibit a consistent relationship for both

sites. Snow densities measured by this project, which are considerably greater than the normal value of 0.1 assumed in AES calculations, should be of assistance in interpreting data for snow accumulations.

c) Snow removal - Snow was removed, from a small part of the drainage basin, only on one occasion. The amount removed was insignificant.

d) Groundwater inflow and outflow, and sewer infiltration - The topography and geology of the study drainage basin are such that the groundwater divide can be assumed to coincide with surface drainage boundaries, i.e. groundwater inflow to the area is not significant. Seepage of water from catchbasins to groundwater is insignificant relative to other flows in the basin, despite the fact that most catchbasins in the area are old and probably leak badly.

The area is underlain by steeply-dipping slate formations of low permeability, and covered with a shallow soil mantle. Sewer and water pipes (street sewers and building sewers) are installed in common trenches in the rock, and this network of trenches appears to provide the route by which groundwater leaves the area. The area is served by combined sewers that are up to 70 years old; all are laid with cement mortar joints. There are a number of other indications that most of the sub-surface drainage finds its way into the sewerage system as infiltration. Storm runoff records obtained in earlier work with this drainage basin (8) indicate considerable amounts of infiltration during and following storm events. These records, together with records of dry weather flow, obtained in this study and the earlier work, and water demand records, will provide a reasonable picture of the groundwater contribution to sewage flow from this basin.

e) Water supply - The Halifax Public Service Commission has recorded average daily flows into the portion of the city that includes this drainage basin. These provide a basis for estimating the average sanitary sewage contribution

from the drainage basin.

f) Sewage flow - The absence of a continuous record of sewage runoff is the most serious obstacle to construction of a long-term water budget for the drainage basin. Nevertheless, a reasonable representation of base flow should be provided by information relating to infiltration discussed above, and by dry weather flow records in this and the earlier study (8).

Precipitation-runoff relationships developed in related projects (9), and winter runoff models that are discussed in the following section of this report, will provide a basis for estimating wet weather runoff and snowmelt volume.

In summary, information obtained by this project should be of value in development or testing of models representing daily or seasonal variations in winter runoff from an urban drainage basin. The information base would have been improved if daily records of snow on the drainage basin had been maintained, and if it had been possible to continuously record combined sewage flow from the drainage basin.

4.1.2 Runoff from winter storms and snowmelt

Runoff in winter storms or snowmelt events can be represented in terms of: precipitation; accumulation and melting of snow (due to elevated temperatures or rainfall); base flow; abstraction by depression storage and infiltration; surface depression storage; and, channel storage in sewers. This project recorded combined sewage flows on three winter rainfall events, and a number of occasions when snowmelt contributed to runoff. Possible application of this information and associated data are discussed below.

a) Precipitation - In addition to daily precipitation data obtained by the project and the local AES station, pluviographs recorded at the AES station during the period of this study are available. A recording rain gauge was installed on the project drainage area during a previous

study (8); that record can be used to provide a correlation with the corresponding AES station record.

b) Snow accumulation and melting - Snow depth and density measurements were obtained before and following the only rainfall event that coincided with a significant snow accumulation; these values will assist in determining the contribution of snowmelt to runoff in that storm.

c) Base flow - As indicated in the previous section, available information makes possible a reasonably precise representation of base flow.

d) Storm runoff - Records of runoff from three winter storms will provide a limited opportunity to test models of winter storm runoff. The records in each storm are incomplete in that they omit the rise and recession of the hydrographs, but they do represent the basic shape of the hydrographs, they include peak flows, and permit an estimate of runoff volume. This project has obtained no data that will contribute to better representation of the following processes that should be represented by a model of winter storm runoff: infiltration, depression storage, detention storage, and pipe storage. Pipe storage models developed for runoff in other seasons should also represent winter runoff. The other process will be affected by frozen ground or snow. A related project (9) has evaluated existing runoff models with spring-summer rainfall data for this drainage basin. When models have been developed that reliably represent runoff in other seasons, the effects of frozen ground or snow on runoff hydrographs can be identified by using rainfall-snowmelt data, for winter storms with measured hydrographs, as inputs to these models.

In summary, hydrographs recorded during three winter storm events, together with precipitation and snow accumulation records, will provide a limited opportunity to test models of winter storm runoff. More and better runoff records are an obvious need, which will be filled when the permanent

recording system is in operation. When reliable models of runoff for other seasons have been developed, they can be used to determine the effect of frozen ground or snow on winter hydrographs.

4.2 Runoff Quality

4.2.1 Long term quality variations

a) Solids inputs - Sources of solids entering the system include sewage solids, solids in dustfall, and/or salt for ice control, dirt and litter, and earth scoured from surfaces in the drainage basin.

For this area, in which the sewers are generally steep and free from deposits (8), sewage solids leaving the area in dry weather flow should represent solids entering the system from this source. Dry weather solids loads from Tables 11 and 12, together with those from the earlier study (8), will provide an adequate description of sewage solids inputs.

Solids in dustfall (precipitation plus dry fallout) recorded by this study were very similar to values recorded in other seasons by earlier studies (8), and nutrient concentrations were comparable with those recorded elsewhere. This information appears to be adequate to represent seasonal inputs from this source.

Comparison of the composition of sand used for ice control and the composition of street surface deposits suggest a strong relationship between them. City records, unfortunately, do not indicate the amount of sand applied to specific streets in the drainage basin; city-wide estimates provide little more than an indication of possible amounts.

Since most surfaces in the drainage basin are paved, roofed or grassed, there has been no recent construction activities, and freezing conditions existed during the period of this study, scour of earth within the basin can be eliminated as a significant solids source. Other sources of dirt and litter, such as earth or sand carried into the area on the wheels or bodies of cars, have not be quantified.

b) Solids outputs - During the period of this study, no solids were removed from the area by cleaning. Solids removed in removed snow were insignificant.

It was expected that the City of Halifax records of solids removed by spring street cleaning would provide an indication of solids accumulation. However, City practice is to make a single pass over the area on each sweeping occasion, removing only part of the accumulated material on each pass. The total accumulation is removed as a result of successive sweeping operations in the period up to June 1st. City records are not sufficiently precise to provide a quantitative estimate of the amount by which materials removed in this period exceeds the amount removed in other seasons. (During the year, sweeper quantities from the area included in this study are in the range 0.3 to 0.8 tons per curb mile per month.)

Dry weather flow composition has been discussed above. It is assumed, in the absence of data, that groundwater infiltration is not a significant source of pollutants; information on nutrient concentrations in the groundwater would be useful.

The scope of this project included sampling of only a few rainfall and snowmelt events, and measurement of combined sewage composition for two storm events and during dry weather. These values will be useful in establishing the order of magnitude of contributions from these sources, but are inadequate for calculation of seasonal mass discharge values.

Even for these few events, mass discharge calculations for surface runoff will be hampered by the necessity to estimate surface runoff rates. Combined sewage mass discharge calculations will be limited by the absence of flow records and samples at the beginning and end of storms. These data must be supplemented with continuous flow records and regular sampling if reliable seasonal mass discharge values are to be calculated.

c) Solids storage - Snow acts as a reservoir for solids, which may be carried away by melting snow or deposited on surfaces by melting. If snow melts over depressions of previous areas from which water escapes by evaporation or infiltration, solids will be deposited permanently. The potential contribution of snowmelt is indicated by samples from snow banks. The results may be low, in that samples were taken behind the curb, and probably contain fewer solids than snow accumulations immediately over street and gutter surfaces.

During winter periods when most surfaces are covered with snow or ice, solids on streets and gutters will present the only significant source of runoff solids. This project attempted to obtain information about the amount and composition of street surface accumulations. The method of solids collection will affect the efficiency with which surface solids are sampled. This project obtained solid samples by sweeping, following the procedure used in APWA study (10). Sartor and Boyd (11) have shown that sweeping leaves behind a significant portion of finer particles and that most of the pollutional characteristics of surface runoff are associated with small particles. No precise estimate of differences due to sampling procedure is possible, but it may be noted that Sartor and Boyd report that solids less than 43μ comprised 5.9% of the total sample, compared with 0.6% to 3.3% less than 53μ in project samples.

Initial solids samples, obtained on January 31, represent accumulations during a one and one-half month period during which streets were not swept, little or no snow accumulated, and rainfall occurred on several days. These samples include solids from a two foot strip adjacent to the curb; Sartor and Boyd's results (11) indicate that about 90% of street solids should be included in this width. Samples taken on March 7 represent a period during which snow

tended to protect street surfaces adjacent to curbs. Rainfall in the absence of snow accumulations preceded sampling on March 21, and it is probable that samples from Sites #1 and #2 on that date represent materials washed from upstream parts of the curb and accumulated in the depressions at the sampling points. The sample from Site #3 on this date is more likely to be representative of accumulations on this relatively steep street.

Estimates of solids retained on surfaces or in depressions will have to be based on information about topography, ground cover, and composition of dustfall, runoff and other solids sources. Accumulation and release of chemicals in soils will be reflected in the composition of water infiltrating into sewers. As noted above, chemical analysis of groundwaters could establish the significance of this nutrient source.

No measurements were made of the amount or composition of solids accumulations in sewers and catch basins. Sewer accumulations are not great in this drainage basin (8). Catchbasins, if not full, will retain larger solids, thus changing the amount and size distribution of solids in surface runoff.

4.2.2 Short term quality variations

During a storm event, the composition of surface runoff depends on contributions from precipitation, solids carried in melting snow, and solids scoured from surfaces. Combined sewage composition reflects contributions from surface runoff, sanitary sewage, infiltration and the modifying effects of solids storage in catchbasins and sewers.

a) Precipitation - Precipitation is ordinarily not an important source of solids, but it may contain significant quantities of nutrients, particularly nitrogen compounds. This project did not obtain explicit data for the composition of precipitation; dustfall measurements included solids in both precipitation and dry fallout. Information from other studies that

have considered the components of dustfall will be of value in estimating the proportion of project dustfall constituents that are attributable to precipitation.

b) Melting snow - Snowbank samples will provide information about the composition of melting snow. A larger number of results, representing a larger sample, more locations, and more analyses, would have been desirable.

c) Surface solids - Although surface solids accumulations were measured on several occasions, the resulting information was inadequate to permit establishing relationships between rainfall rates or volumes and changes in amounts or composition of surface accumulations. The information obtained was adequate to demonstrate that surface deposits can account for the composition of surface runoff.

d) Surface runoff and combined sewage composition - Interpretation of information about the composition of winter surface runoff from small areas should take into consideration that composition is likely to be more variable than in other seasons, because of dams that retain solids until the dams melt and release accumulated materials, and because melting snow can alter runoff composition by dilution or by addition of solids.

Project data for surface runoff composition should be of value in testing the application of surface runoff quality models to winter runoff conditions. For the February 20th storm, for which information about surface runoff, dry weather flow and combined sewage composition is available, the ability of models to represent the complete system can be tested.

REFERENCES

1. American Public Health Association, Standard Methods for the Examination of Water and Wastewaters, A.P.H.A., N.Y., 1971.

2. Wyckoff, B.M., "Rapid Solids Determination Using Glass Fiber Filters", Water and Sewage Works 2(6), 1964.

3. Westerhold, A.F., "Measurement of Waste", The Digester, Illinois Dept. of Public Health 22(2), 1965.

4. MacNeil, F.W., "Determination of ODI", Nova Scotia Dept. of Health, unpublished, 1971.

5. Environment Canada, "Precipitation", Atmospheric Environment, Environment Canada, 1973.

6. American Society for Testing and Materials, "Standard Method for Collection and Analysis of Dustfall", ASTM Designation: D1739-70, 1970.

7. McCurdy, Ross F., "Oxygen Demand Index: Its Relationship to BOD and COD", unpublished course paper, University of Minnesota, 1973.

8. Waller, D.H., "Pollution Attributable to Surface Runoff and Overflows from Combined Sewerage Systems", Central Housing and Mortgage Corporation, Ottawa, 1971.

9. Waller, D.H., W.A. Coulter, W.M. Carson, and D.G. Bishop, "Urban Drainage Model Comparison for a Catchment in Halifax, Nova Scotia", Canada-Ontario Agreement Project No. 74-8-2, in press.

10. American Public Works Assoc., "Water Pollution Aspects of Urban Runoff", Federal Water Pollution Control Administration, Water Pollution Control Research Series Wp-20-15, January 1969.

11. Sartor, James D., and Gail B. Boyd, "Water Pollution Aspects of Street Surface Contaminants", Office of Research and Monitoring, U.S. Environmental Protection Agency Report EPA-R2-72-081, November 1972.

ACKNOWLEDGEMENTS

A significant portion of the information presented in this report was collected by Gary B. Hubbard, Keith C. Ring, and Douglas G. Smith, for a report prepared in fulfillment of the requirements of a senior course in Civil Engineering at the Nova Scotia Technical College*. Their interest and enthusiasm was an important contribution to the project.

The Nova Scotia Department of Public Health provided most of the analytical support for this project. Particular thanks are due to C.E. Tupper, P. Eng., Director of Environmental Engineering, who arranged to conduct bacteriological tests at no cost to the project, and to Mr. Ross McCurdy and Mr. Robert Samara, who were responsible for chemical and bacteriological analyses.

The City of Halifax provided continuing cooperation in access to their facilities and records. Thanks are due to Mr. M.J. Sheflin, Director of Works, and to the staff at City Field, particularly Messrs. Vellis and Krauch.

The Atmospheric Environment Service, Department of the Environment, has given invaluable assistance in loaning equipment and providing advice regarding its installation and operation.

The interest and support of the Urban Drainage Subcommittee under the Canada-Ontario Agreement on Great Lakes Water Quality made this project possible.

---

* G.B. Hubbard, K.C. Ring, and D.G. Smith "Solids Accumulation in Snowmelt and Runoff", unpublished report prepared for Course 199, Department of Civil Engineering, Nova Scotia Technical College, 1974.

APPENDIX

METEOROLOGICAL DATA FOR MONTHS OF JANUARY, FEBRUARY, MARCH, 1974

Halifax-Dartmouth, Nova Scotia
Shearwater "A"

Source: Monthly Meteorological Summary
Atmospheric Environment Service
Environment Canada

ATMOSPHERIC ENVIRONMENT SERVICE
DEPARTMENT OF THE ENVIRONMENT CANADA

MONTHLY METEOROLOGICAL SUMMARY

FOR THE MONTH OF JANUARY, 1974 AT HALIFAX-DARTMOUTH, N.S. (Shearwater "A")

LAT: 44 ° 38 ' LONG: 63 ° 30 ' ELEVATION: 178 FEET. STANDARD TIME USED: Atlantic

DATE	TEMPERATURE (°F)			DEGREE DAYS BELOW 65°F	RELATIVE HUMIDITY (%)				WIND (M.P.H.)			DURATION OF BRIGHT SUNSHINE (HOURS)	GROWING DEGREE DAYS ABOVE 42°
	MAXIMUM	MINIMUM	MEAN FROM MAX AND MIN		2 AM	8 AM	2 PM	8 PM	AVERAGE SPEED	PREVAILING DIRECTION	MAXIMUM SPEED AND DIRECTION		
1	44	26	35	30	90	88	97	100	10.3	E, NE	16 E	0.0	
2	37	12	25	40	90	72	56	53	15.9	NW	22 NW	8.0	
3	25	9	17	48	55	75	60	79	9.1	NW	18 NW	7.2	
4	22	12	17	48	64	58	48	52	5.4	NNE	14 NW	5.6	
5	23	12	18	47	85	69	57	64	10.0	NW	17 NW	8.2	
6	31	13	22	43	76	69	71	77	5.3	W	12 W	3.9	
7	30	17	24	41	82	87	71	96	3.4	NE	8 NNE	1.8	
8	28	6	17	48	86	71	53	51	15.0	WNW	24 WNW	6.2	
9	12	3	8	57	65	75	62	73	12.7	WNW	22 WNW	2.3	
10	19	2	11	54	77	76	52	57	4.3	N	8 WNW	4.4	
11	22	17	20	45	65	84	92	94	10.3	NE	16 NE	0.0	
12	24	4	14	51	95	91	85	84	11.8	NNE	18 NNE	1.0	
13	7	-2	3	62	84	73	67	79	10.5	NW	16 NW	8.1	
14	37	-5	16	49	75	80	59	83	11.7	SSW	33 SSW	7.7	
15	41	22	32	33	87	77	57	62	18.6	W	38 SSW	0.0	
16	22	-1	11	54	85	72	74	81	10.0	NNE	17 NNE	0.4	
17	1	-9	-4	69	78	56	57	75	14.3	NW	18NNW,NW	8.5	
18	17	0	9	56	72	70	39	66	11.1	NW	16 WNW	9.0	
19	39	8	24	41	86	91	100	75	12.8	WNW	24 WNW	0.8	
20	19	5	12	53	79	82	68	84	11.0	NNW	21 NW	8.9	
21	37	6	22	43	86	82	85	97	7.1	ESE	13 ESE	3.8	
22	46	32	39	26	100	95	98	95	13.0	SSE,SW	22 SSE	0.6	
23	42	26	34	31	77	84	87	97	9.9	SW	16 SW	4.6	
24	43	31	37	28	100	86	67	67	10.5	WNW	17 WNW	7.7	
25	41	28	35	30	73	82	52	82	8.2	W,WNW	18 WNW	8.2	
26	32	25	29	36	80	83	65	79	4.7	NE	12 NNE	6.4	
27	47	30	39	26	87	94	98	100	15.8	SE	25 SW	0.0	
28	47	32	40	25	79	75	66	86	10.2	WSW,W	24 W	6.6	
29	42	30	36	29	97	100	79	86	12.3	NW	28 E	4.1	
30	34	27	31	34	71	84	91	92	7.0	SE	11 SE	0.4	
31	45	34	40	25	89	100	83	90	11.1	SW	17 S	0.0	
MEAN	30.8	14.6	22.7	Total 1302	81	80	71	79	10.4	Prevailing WNW	Maximum 38 SSW	Total 134.4	Total 0
NORMAL	32.3	18.0	25.2	1228	82	84	76	81	15.5	WNW	35 SW	110.1	1

UDC 551.506 1 (716.12)

PRECIPITATION (INCHES) (1)				
DATE	RAINFALL	SNOWFALL	(2) TOTAL PRECIP	(3) DEPTH OF SNOW ON GROUND
1.	0.21		0.21	1
2.		TR	TR	0
3.		TR	TR	0
4.				0
5.		TR	TR	0
6.		1.0	0.06	0
7.		1.0	0.04	1
8.		TR	TR	2
9.				1
10.				TR
11.		2.9	0.21	TR
12.	TR	1.2	0.15	4
13.		0.2	0.01	4
14.	TR	TR	TR	4
15.	0.06	0.2	0.09	1
16.		0.3	0.03	TR
17.		TR	TR	TR
18.				TR
19.	0.18	4.8	0.88	1
20.				4
21.				4
22.	0.30		0.30	1
23.	0.22		0.22	TR
24.	0.01		0.01	TR
25.				TR
26.		TR	TR	TR
27.	1.04	TR	1.04	TR
28.	TR		TR	TR
29.	0.67	TR	0.67	TR
30.		TR	TR	TR
31.	0.10		0.10	TR
TOTAL	2.79	11.6	4.02	--
NORMAL	3.92	18.7	5.80	--

DAILY WEATHER SUMMARY FOR JANUARY, 1974, AT HALIFAX-DARTMOUTH, N.S

1. Overcast. Rain, freezing rain, drizzle and fog. Very mild.
2. Sunny. Mild.
3. Mostly sunny. Very cold.
4. Cloudy, clearing by midday. Extremely cold.
5. Mostly sunny. Early morning flurries. Cold.
6. Mostly overcast. Snow and flurries in the morning. Seasonable temperatures.
7. Mostly overcast. Snow and flurries late afternoon and evening. Cold.
8. Cloudy, clearing early afternoon. Scattered flurries. Very cold.
9. Cloudy, clearing in evening. Extremely cold.
10. Sunny, becoming overcast in afternoon. Extremely cold.
11. Overcast. Flurries, snow, ice pellets, freezing rain and freezing drizzle. Seasonable temperatures.
12. Mostly overcast. Snow. Very cold.
13. Mostly sunny. Flurries morning and evening. Extremely cold.
14. Sunny, becoming overcast late afternoon. Flurries and showers. Cold.
15. Overcast. Showers early morning, snow in evening. Mild.
16. Mostly overcast. Snow early morning and evening. Extremely cold.
17. Mostly sunny. Flurries early afternoon. Extremely cold.
18. Sunny. Extremely cold.
19. Mostly cloudy. Snow, snow grains, flurries and rain. Seasonable temperatures.
20. Mostly sunny. Extremely cold.
21. Mostly overcast. Cold.
22. Overcast. Rain and fog. Extremely mild.
23. Mostly cloudy. Showers, drizzle and fog late evening. Mild.
24. Mostly cloudy. Drizzle and fog early morning. Extremely mild.
25. Mostly cloudy. Mild.
26. Cloudy morning and evening. Early morning flurries. Seasonable temperatures.
27. Mostly overcast. Rain, drizzle, snow pellets and fog in the morning. Extremely mild.
28. Cloudy. Extremely mild.
29. Mostly overcast. Showers and rain early morning. Extremely mild.
30. Cloudy. Flurries in afternoon. Mild.
31. Mostly overcast. Drizzle, showers, fog. Extremely mild.

DAYS WITH TOTAL PRECIPITATION					DAYS WITH SNOWFALL					THUNDERSTORMS		
0.01" OR MORE	0.04" OR MORE	0.25" OR MORE	0.50" OR MORE	1.00" OR MORE	0.1" OR MORE	0.4" OR MORE	2.5" OR MORE	5.0" OR MORE	10.0" OR MORE	NO.	NORMAL	DATES
15	12	4	3	1	8	5	2	0	0	Nil	0.1	--

(1) TR = Trace = negligible amount of rain or snow. Precipitation data are based on 24-hour period beginning 2:00 a.m., AST.

(2) Total precipitation is computed by adding rainfall in inches to water equivalent of the snowfall in inches.

(3) Measurement taken at 8:00 a.m., AST.

ATMOSPHERIC ENVIRONMENT SERVICE
DEPARTMENT OF THE ENVIRONMENT CANADA

MONTHLY METEOROLOGICAL SUMMARY

FOR THE MONTH OF FEBRUARY, 1974 AT HALIFAX-DARTMOUTH, N.S. (Shearwater "A")

LAT: 44 °38 ' LONG: 63 °30 ' ELEVATION: 178 FEET. STANDARD TIME USED: Atlantic

DATE	TEMPERATURE (°F)			DEGREE DAYS BELOW 65°F	RELATIVE HUMIDITY (%)				WIND (M.P h.)			DURATION OF BRIGHT SUNSHINE (HOURS)	GROWING DEGREE DAYS ABOVE 42°
	MAXIMUM	MINIMUM	MEAN FROM MAX AND MIN		2 AM	8 AM	2 PM	8 PM	AVERAGE SPEED	PREVAILING DIRECTION	MAXIMUM SPEED AND DIRECTION		
1	45	10	28	37	89	45	67	51	21.6	W	30 WNW	9.2	
2	17	8	13	52	50	69	53	54	15.5	W	23 W	7.5	
3	22	6	14	51	42	63	40	54	11.0	NW	17 NW	9.4	
4	21	8	15	50	69	76	41	69	6.4	NE	13 NE	5.7	
5	22	14	18	47	78	90	92	93	22.6	NE	31 N	0.0	
6	27	17	22	43	93	83	70	84	15.5	NW	24 NW	6.9	
7	24	15	20	45	82	91	95	95	6.9	NW	17 N	0.4	
8	25	15	20	45	94	85	68	83	7.8	NW	14 NNW	8.1	
9	24	12	18	47	84	78	57	71	8.3	WNW	15 WNW	3.4	
10	22	7	15	50	70	76	58	64	9.3	WNW	17 WNW	9.2	
11	29	12	21	44	76	70	76	85	6.4	W	14 S	6.8	
12	27	14	21	44	92	82	74	78	9.6	NE	16 N	2.1	
13	42	16	29	36	90	82	75	94	12.7	S	25 SSW	3.9	
14	41	0	21	44	95	95	85	69	12.3	N	24 NNW	0.5	
15	21	-2	10	55	74	76	64	60	6.2	W	13 W	10.0	
16	26	8	17	48	69	70	55	52	10.2	W	15 W	7.9	
17	26	12	19	46	70	80	96	95	14.8	NE	30 NE	0.0	
18	26	15	21	44	95	94	85	75	16.8	NW	31 N	0.0	
19	30	6	18	47	63	76	58	72	6.2	WNW	10 SE	9.5	
20	44	29	37	28	88	100	100	100	17.3	SE	28 E	0.0	
21	37	29	33	32	89	71	59	62	17.4	NW	26 NW	8.3	
22	40	25	33	32	68	77	78	84	8.3	ESE	19 ESE	2.9	
23	48	26	37	28	100	100	83	99	22.8	SW	34 SE	0.6	
24	27	19	23	42	77	69	64	67	14.7	WNW	22 W	6.3	
25	29	15	22	43	81	84	98	96	9.2	NE	18 NE	0.0	
26	28	18	23	42	88	92	76	83	8.0	N	15 N	0.4	
27	31	14	23	42	74	76	67	74	6.7	NW	12 WNW	10.7	
28	36	22	29	36	86	89	73	92	10.2	SW	17 SW	2.3	
29													
30													
31													
MEAN	29.9	13.9	21.9	Total 1200	80	80	72	77	12.0	Prevailing NW	Maximum 34 SE	Total 132.0	Total 0
NORMAL	31.8	17.0	24.4	1141	83	82	71	80	13.7	WNW	36NE,SE	128.8	0

UDC 551.506 1 (716.12)

AE 0063-9821
Sheet 1 (Rev)

PRECIPITATION (INCHES) (1)

DATE	RAINFALL	SNOWFALL	(2) TOTAL PRECIP	(3) DEPTH OF SNOW ON GROUND
1.	TR	TR	TR	TR
2.				TR
3.				TR
4.		TR	TR	TR
5.		11.4	1.14	3
6.		0.4	0.04	12
7.		5.8	0.55	12
8.		TR	TR	18
9.				17
10.				17
11.		TR	TR	12
12.		0.1	0.01	9
13.	0.06		0.06	8
14.	TR	0.4	0.02	5
15.				5
16.				3
17.		9.2	1.86	3
18.		6.1	0.59	15
19.				18
20.	1.07	0.1	1.08	12
21.		TR	TR	4
22.	0.56		0.56	3
23.	0.52	1.4	0.64	TR
24.		TR	TR	1
25.		5.4	0.42	1
26.		TR	TR	6
27.				5
28.		TR	TR	4
TOTAL	2.21	40.3	6.97	--
NORMAL	2.91	21.0	5.06	--

DAILY WEATHER SUMMARY FOR FEBRUARY, 1974, AT HALIFAX-DARTMOUTH, N.S

1. Mostly sunny. Scattered flurries and showers. Mild.
2. Sunny, becoming overcast in evening. Very cold.
3. Sunny. Very cold.
4. Sunny, becoming overcast in evening. Cold.
5. Overcast. Snow and blowing snow. Cold.
6. Cloudy. Snow early morning. Seasonable temperatures.
7. Mostly overcast. Snow, at times heavy, afternoon and evening. Cold.
8. Sunny, becoming cloudy in afternoon. Snow early morning. Cold.
9. Mostly overcast, clearing late afternoon. Cold.
10. Sunny. Very cold.
11. Mostly cloudy. Flurries in evening. Cold.
12. Cloudy, clearing in afternoon. Snow and flurries in the morning. Seasonable temperatures.
13. Mostly cloudy. Showers in evening. Mild.
14. Mostly overcast, clearing in evening. Showers and flurries. Seasonable temperatures.
15. Sunny. Extremely cold.
16. Mostly sunny. Cold.
17. Overcast. Snow, at times moderate. Cold.
18. Mostly overcast. Snow, at times heavy, in the morning. Cold.
19. Sunny, becoming cloudy in evening. Cold.
20. Overcast. Flurries, freezing rain, rain and fog. Extremely mild.
21. Cloudy, clearing in the morning. Flurries. Very mild.
22. Mostly overcast. Rain, at times heavy, in evening. Very mild.
23. Overcast. Early morning rain. Snow late afternoon. Fog. Extremely mild.
24. Mostly overcast. Flurries in morning. Seasonable temperatures.
25. Overcast. Snow. Cold.
26. Mostly overcast. Early morning flurries. Cold.
27. Mostly sunny. Seasonable temperatures.
28. Mostly cloudy. Seasonable temperatures.

DAYS WITH TOTAL PRECIPITATION					DAYS WITH SNOWFALL					THUNDERSTORMS		
0.01" OR MORE	0.04" OR MORE	0.25" OR MORE	0.50" OR MORE	1.00" OR MORE	0.1" OR MORE	0.4" OR MORE	2.5" OR MORE	5.0" OR MORE	10.0" OR MORE	NO.	NORMAL	DATES
12	10	8	7	3	10	8	5	5	1	Nil	0.1	--

(1) TR = Trace = negligible amount of rain or snow. Precipitation data are based on 24-hour period beginning 2:00 a.m., AST.

(2) Total precipitation is computed by adding rainfall in inches to water equivalent of the snowfall in inches.

(3) Measurement taken at 8:00 a.m., AST.

ATMOSPHERIC ENVIRONMENT SERVICE
DEPARTMENT OF THE ENVIRONMENT CANADA

MONTHLY METEOROLOGICAL SUMMARY

FOR THE MONTH OF MARCH, 1974 AT HALIFAX-DARTMOUTH, N.S. (Shearwater "A")

LAT: 44 ° 38 ' LONG: 63 ° 30 ' ELEVATION: 178 FEET. STANDARD T ME : SED· Atlantic

DATE	TEMPERATURE (°F)			DEGREE DAYS BELOW 65°F	RELATIVE HUMIDITY (%)				WIND (M.P .			DURATION OF BRIGHT SUNSHINE (HOURS)	GROWING DEGREE DAYS ABOVE 42°
	MAXIMUM	MINIMUM	MEAN FROM MAX AND MIN		2 AM	8 AM	2 PM	8 PM	AVERAGE SPEED	PREVAILING DIRECTION	MAXIMUM SPEED AND DIRECTION		
1	41	35	38	27	92	95	100	100	10.0	S	16 S	0.0	
2	37	17	27	38	92	81	60	64	11.1	N	16 N	8.4	
3	29	11	20	45	82	73	53	69	11.4	SE	18 SE	9.1	
4	46	28	37	28	87	97	98	98	13.5	SW	25 SSW	0.0	
5	48	37	43	22	100	100	87	85	12.0	SW	17 SW	0.0	1
6	47	35	41	24	85	76	45	64	11.3	WSW	18 NW	9.6	
7	49	35	42	23	74	84	80	93	12.5	SW	19 NW	7.9	
8	38	20	29	36	40	54	55	48	15.8	NW	20 NW	8.8	
9	31	16	24	41	55	54	38	47	10.7	NW	16 NW	9.5	
10	31	16	24	41	61	75	91	96	9.8	SE	23 N	0.0	
11	22	9	16	49	80	71	68	60	17.3	NW	23 NNW	9.0	
12	15	5	10	55	72	85	54	47	17.0	WNW	23 WNW	9.9	
13	21	8	15	50	75	79	69	65	13.4	WNW	16 WNW	5.7	
14	36	20	28	37	73	80	70	69	12.1	NW	16 WNW	6.5	
15	40	23	32	33	88	72	48	85	7.1	WNW	14 N	10.0	
16	38	22	30	35	92	90	77	91	6.6	SE	14 SE	7.6	
17	45	32	39	26	94	95	98	94	18.1	ESE	29 SE	0.8	
18	37	31	34	31	97	94	76	74	14.1	SW	18 SW	6.1	
19	37	32	35	30	71	62	66	91	11.9	SW	15 SW	4.7	
20	36	18	27	38	92	82	48	43	11.6	W	17 WNW	9.8	
21	49	17	33	32	59	59	79	91	12.9	ESE	30 S	4.4	
22	43	30	37	28	98	67	46	73	15.7	W	31 SW	10.0	
23	39	26	33	32	82	65	51	81	11.0	S	17 W	10.2	
24	50	35	43	22	97	93	100	100	14.4	SE	20 SE	0.0	1
25	36	19	28	37	84	48	48	42	15.5	WNW	23 W	10.6	
26	32	15	24	41	68	52	59	69	9.3	SW	18 SSW	5.6	
27	34	16	25	40	97	67	75	58	19.2	NW	27 NW	9.3	
28	24	11	18	47	51	72	46	49	14.9	NW	18 NW	9.9	
29	33	12	23	42	54	54	47	42	12.4	NW	17 NW	10.7	
30	33	15	24	41	65	71	62	69	10.1	E	18 E	10.5	
31	40	31	36	29	82	97	100	100	15.7	E	30 E	0.0	
MEAN	36.7	21.8	29.3	Total 1100	79	76	68	73	12.8	Prevailing NW	Maximum 56 S	Total 204.6	Total 2
NORMAL	37.5	23.8	30.7	1061	81	81	70	74	14.6	WNW	36 E	148.1	1

UDC 551.506 1 (716.12)

AE 0063-9821
Sheet 1 (Rev)

PRECIPITATION (INCHES) (1)

DATE	RAINFALL	SNOWFALL	(2) TOTAL PRECIP	(3) DEPTH OF SNOW ON GROUND
1.	0.24		0.24	2
2.		0.3	0.03	1
3.		TR	0.01	1
4.	0.07		0.07	1
5.	TR		TR	TR
6.				TR
7.				TR
8.				TR
9.				TR
10.		4.1	0.42	TR
11.		TR	TR	4
12.		TR	TR	4
13.		TR	TR	3
14.		0.3	0.02	3
15.				1
16.	TR		TR	TR
17.	0.66		0.66	TR
18.		0.2	0.02	TR
19.		0.1	0.01	TR
20.		TR	TR	TR
21.	1.11	2.2	1.33	TR
22.		TR	TR	TR
23.				TR
24.	0.33		0.33	TR
25.	0.01	0.1	0.02	TR
26.		0.8	0.06	TR
27.		0.4	0.04	1
28.				TR
29.				TR
30.				TR
31.	0.71		0.71	TR
TOTAL	3.13	8.5	3.97	--
NORMAL	2.81	15.8	4.40	--

DAILY WEATHER SUMMARY FOR MARCH, 1974, AT HALIFAX-DARTMOUTH, N.S.

1. Overcast. Rain, drizzle, showers and fog. Very mild.
2. Mostly cloudy. Snow late evening. Seasonable temps.
3. Cloudy morning and evening. Snow early morning. Cold.
4. Overcast. Freezing rain and freezing drizzle. Rain, drizzle and fog. Very mild.
5. Mostly overcast. Showers, drizzle and fog. Extremely mild.
6. Sunny. Extremely mild.
7. Mostly cloudy. Extremely mild.
8. Sunny. Seasonable temperatures.
9. Sunny. Cold.
10. Overcast. Snow and blowing snow. Cold.
11. Mostly cloudy. Flurries. Extremely cold.
12. Sunny. Extremely cold.
13. Cloudy, clearing in afternoon. Scattered flurries. Extremely cold.
14. Cloudy. Flurries in evening. Seasonable temperatures.
15. Sunny. Seasonable temperatures.
16. Cloudy afternoon and evening. Showers in evening. Seasonable temperatures.
17. Mostly overcast. Rain, ending early afternoon. Very mild.
18. Cloudy. Flurries in morning. Mild.
19. Mostly overcast. Flurries afternoon and evening. Mild.
20. Mostly sunny. Early morning flurries. Cold.
21. Mostly overcast. Freezing rain, ice pellets and rain, late afternoon and evening. Seasonable temperatures.
22. Mostly sunny. Mild.
23. Sunny. Seasonable temperatures.
24. Mostly overcast. Showers and rain. Fog. Very mild.
25. Mostly sunny. Early morning flurries. Cold.
26. Mostly sunny. Flurries late evening. Very cold.
27. Cloudy. Flurries. Very cold.
28. Mostly sunny. Extremely cold.
29. Sunny. Very cold.
30. Mostly overcast. Very cold.
31. Overcast. Freezing rain, rain, drizzle, thunder showers and fog. Seasonable temperatures.

DAYS WITH TOTAL PRECIPITATION					DAYS WITH SNOWFALL					THUNDERSTORMS		
0.01" OR MORE	0.04" OR MORE	0.25" OR MORE	0.50" OR MORE	1.00" OR MORE	0.1" OR MORE	0.4" OR MORE	2.5" OR MORE	5.0" OR MORE	10.0" OR MORE	NO.	NORMAL	DATES
15	9	5	3	1	9	4	1	0	0	1	0.1	31st

(1) TR = Trace = negligible amount of rain or snow. Precipitation data are based on 24-hour period beginning 2:00 a.m., AST.

(2) Total precipitation is computed by adding rainfall in inches to water equivalent of the snowfall in inches.

(3) Measurement taken at 8:00 a.m., AST.

ATMOSPHERIC ENVIRONMENT SERVICE
DEPARTMENT OF THE ENVIRONMENT CANADA

MONTHLY METEOROLOGICAL SUMMARY

FOR THE MONTH OF APRIL, 1974 AT HALIFAX-DARTMOUTH, N.S. (Shearwater "A")

LAT: 44 ° 38 ' LONG: 63 ° 30 ' ELEVATION: 178 FEET. STANDARD TIME USED: Atlantic

DATE	TEMPERATURE (°F)			DEGREE DAYS BELOW 65°F	RELATIVE HUMIDITY (%)				WIND (M.P.H.)			DURATION OF BRIGHT SUNSHINE (HOURS)	GROWING DEGREE DAYS ABOVE 42°
	MAXIMUM	MINIMUM	MEAN FROM MAX AND MIN		2 AM	8 AM	2 PM	8 PM	AVERAGE SPEED	PREVAILING DIRECTION	MAXIMUM SPEED AND DIRECTION		
1	41	35	38	27	100	98	85	74	9.9	WNW	17 WNW	0.1	
2	46	30	38	27	77	74	62	89	9.8	WNW	18 NW	6.7	
3	38	30	34	31	100	91	79	81	6.5	NW	12 NW	2.4	
4	45	31	38	27	97	89	95	100	9.1	ESE	18 ESE	2.1	
5	53	40	47	18	100	100	98	100	8.8	SW	18 SW	0.8	
6	49	37	43	22	100	100	100	98	8.2	E	24 SW	0.8	1
7	49	35	42	23	90	81	34	63	13.6	WNW	17 W	8.5	
8	45	30	38	27	82	83	62	60	11.7	SW	25 SW	1.5	
9	43	27	35	30	73	77	97	99	15.6	ENE	24 E	0.0	
10	45	32	39	26	100	100	100	97	12.8	S	16 SW,S	0.0	
11	38	30	34	31	97	91	79	73	12.5	WNW	22 WNW	0.9	
12	45	28	37	28	70	53	44	57	12.0	W	19 WNW	12.2	
13	37	28	33	32	63	73	64	70	7.0	SE	15 S	5.4	
14	37	32	35	30	83	84	86	100	11.7	E	18 E	0.0	
15	45	35	40	25	100	100	100	100	11.6	SE	22 SSE	0.0	
16	46	34	40	25	98	77	60	54	13.4	W	22 W		
17	57	32	45	20	74	58	42	58	11.0	WNW	16W,WNW		2
18	52	35	44	21	75	93	65	86	10.0	SW	17 SW		2
19	47	32	40	25	89	89	31	82	9.7	NNW	20 NNE		
20	45	29	37	28	89	62	26	50	9.7	NW	18 NW		
21	54	27	41	24	79	62	50	75	6.5	SW,WNW	14 SW		
22	55	38	47	19	70	78	98	93	4.4	ESE	10 SSE		4
23	50	36	43	22	93	98	92	93	8.3	SW	15 NNE		1
24	38	33	36	30	95	87	95	97	12.4	NE	17 NNE		
25	43	32	38	27	97	92	67	79	10.3	NNE	14 NE		
26	36	31	34	31	94	93	92	82	13.1	NNE	18 N		
27	58	34	46	19	82	80	34	63	9.1	SW	18 SSW		4
28	62	39	51	14	63	74	54	78	10.8	SW	16 SW		9
29	52	43	48	17	87	91	88	100	14.6	SW	22 SW	4.2	5
30	57	37	47	18	100	86	70	77	9.3	N	15N,NW	10.2	5
31													
MEAN	46.9	33.1	40.0	Total 744	87	84	72	81	10.5	Prevailing SW	Maximum 46 E	Total 141.4	Total 33
NORMAL	46.6	31.8	39.2	770	83	79	64	78	13.0	WNW	34 E	176.0	25

UDC 551.506.1 (716.22)

PRECIPITATION (INCHES) (1)

DATE	RAINFALL	SNOWFALL	(2) TOTAL PRECIP	(3) DEPTH OF SNOW ON GROUND
1.	0.28		0.28	TR
2.	0.05	2.4	0.29	TR
3.		0.8	0.06	4
4.	0.36		0.36	TR
5.	0.28		0.28	0
6.	0.71		0.71	0
7.	TR	TR	TR	0
8.	0.02		0.02	0
9.	0.55	1.1	0.67	1
10.	0.19	TR	0.19	TR
11.		0.4	0.04	TR
12.				0
13.	TR	0.1	0.01	0
14.	TR	TR	TR	0
15.	0.11		0.11	0
16.	TR	TR	TR	0
17.				0
18.				0
19.				0
20.		TR	TR	0
21.				0
22.	0.03		0.03	0
23.	0.16		0.16	0
24.	0.09	0.4	0.13	0
25.	0.01	TR	0.01	0
26.		4.4	0.45	1
27.				TR
28.				0
29.	TR		TR	0
30.	0.01		0.01	0
TOTAL	2.85	9.6	3.81	--
NORMAL	3.63	4.7	4.15	--

DAILY WEATHER SUMMARY FOR APRIL, 1974, AT HALIFAX-DARTMOUTH, NS

1. Cloudy. Early morning showers and drizzle. Seasonable temperatures.
2. Cloudy. Showers, snow and ice pellets in the evening. Seasonable temperatures.
3. Cloudy. Scattered flurries. Seasonable temperatures.
4. Cloudy. Showers, drizzle and fog afternoon and evening. Seasonable temperatures.
5. Overcast. Showers, drizzle and rain in the evening. Fog. Very mild.
6. Overcast. Showers, drizzle, rain and fog. Mild.
7. Cloudy morning and evening. Early morning flurries. Seasonable temperatures.
8. Mostly overcast. Early morning showers. Seasonable temperatures.
9. Overcast. Snow, freezing rain, ice pellets, drizzle and fog afternoon and evening. Seasonable temperatures
10. Overcast. Drizzle and fog. Flurries and showers in the evening. Seasonable temperatures.
11. Mostly cloudy. Flurries. Cold.
12. Sunny. Seasonable temperatures.
13. Mostly cloudy. Late evening showers and ice pellets. Cold.
14. Overcast. Flurries, and ice pellets in the morning. Drizzle and fog afternoon and evening. Seasonable temperatures.
15. Overcast. Drizzle, rain, showers and fog. Seasonable temperatures.
16. Mostly cloudy. Seasonable temperatures.
17. Sunny. Mild.
18. Mostly sunny. Seasonable temperatures.
19. Sunny, becoming cloudy late evening. Seasonable temps.
20. Mostly sunny. Early morning flurries. Seasonable temperatures.
21. Mostly overcast. Seasonable temperatures.
22. Mostly overcast. Mid-day showers. Mild.
23. Overcast. Rain, drizzle, showers and fog. Seasonable temperatures.
24. Overcast. Showers, rain, ice pellets and flurries. Cold.
25. Mostly overcast. Seasonable temperatures.
26. Mostly overcast. Flurries and snow in the morning. Cold.
27. Mostly sunny. Mild.
28. Cloudy afternoon and evening. Very mild.
29. Cloudy. Drizzle and fog afternoon and evening. Mild.
30. Mostly cloudy. Mild.

Great Lakes Surveys Unit
Water Resources Branch
Ministry of the Environment
135 St. Clair Avenue West

DAYS WITH TOTAL PRECIPITATION					DAYS WITH SNOWFALL					THUNDERSTORMS		
0.01" OR MORE	0.04" OR MORE	0.25" OR MORE	0.50" OR MORE	1.00" OR MORE	0.1" OR MORE	0.4" OR MORE	2.5" OR MORE	5.0" OR MORE	10.0" OR MORE	NO.	NORMAL	DATES
18	13	7	2	0	7	6	1	0	0	Nil	0.5	

(1) TR = Trace = negligible amount of rain or snow. Precipitation data are based on 24-hour period beginning 2:00 a.m., AST.

(2) Total precipitation is computed by adding rainfall in inches to water equivalent of the snowfall in inches.

(3) Measurement taken at 8:00 a.m., AST.

425

Date Due

NLR 176

TD
657
.W35
W56
1974

Winter runoff from an urban catchment : (January to March 1974) / Waller, D. H.

78812

Great Lakes Surveys Unit
Water Resources Branch
Ministry of the Environment
135 St. Clair Avenue West
Toronto, Ontario, Canada
M4V 1P5